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AMERICAN RAILWAY ENGINEERING ASSOCIATION
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Chicago, 5, Illinois

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REVISIONS AND CORRECTIONS

AREA Proceedings, Volume 49 (1948)

Changes in the text for correction of typographical errors, and to take account of revisions, deletions and additions requested by committees.

Page 90, first line, after "thereof" add "and where superelevation would not indicate otherwise."

Page 96, next to last line, change "(a)" to "(e)."

Page 97, eighth line, change *"Prospect"* to *"Project."*

Page 99, footnote reference line should appear as fifth line on page 100.

Page 120, ASTM reference in third paragraph from bottom of page should read "A 273" instead of "A 17."

Page 123, in committee roster, change "C. J. McCarty" to read "C. E. McCarty."

Page 131, first line, change "United States Army" to read "Department of the Army."

Page 140, tenth line, change "eliminate" to "reduce."

Page 152, second line of sixth paragraph, change "eight" to "twelve."

Page 161, fifth line of second paragraph, change "more" to "move."

Page 203, replace first paragraph by "Material repaired by welding will be rejected."

Page 268, at end of second sentence under "Packing," add a new sentence as follows: "When treated timber lining is used, packing of timber shall be treated as outlined in Paragraph 4."

Page 292, in table, third column, third line, change "200" to "185;" in same column tenth line, change "240" to "200;" in seventh column, change last figure from "221" to "227."

Page 296, add "W. C. Sadler" to personnel of subcommittee.

Page 426, fifth paragraph, third line, change "greater then" to "greater than."

Page 427, last paragraph, fourth line, change "contract" to "contact."

Page 434, in subcommittee personnel, replace "Armstrong Chinn" by "H. Austill."

Page 458, in cut caption, change "Figs. 33 and 34" to "Figs. 17 and 18."

Page 495, in cut captain, change "thread" to "tread."

Report of Committee 16—Economics of Railway Location and Operation

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Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, submitted as information ..... page 2
2. Methods for obtaining more intensive use of existing railway facilities.
   No report.
3. Methods or formulas for the solution of special problems relating to more economical and efficient railway operation.
   Progress report, submitted as information ..... page 14
4. Effect of higher speed on railway revenues, operating expenses, and charges to capital account.
   No report.
5. Electrification and the development of modern power units; their influence on railway economics, collaborating with Electrical Section, Engineering Division, and Mechanical Division, AAR.
   Progress report, submitted as information ..... page 22
6. General course of the cost of railway transportation and operation over the past 100 years; principal determining elements and economic significance.
   Progress report, submitted as information ..... page 28
7. Coordinated highway service and its effect on the economics of railway operation.
   Final report, submitted as information ..... page 45
8. Economics of operation of union railway passenger terminals.
   No report.

The Committee on Economics of Railway Location and Operation,
F. N. Nye, *Chairman.*

AREA Bulletin 469, November 1947.

Report on Assignment 1

Revision of Manual

E. E. Kimball (chairman, subcommittee), E. G. Allen, B. T. Anderson, J. W. Barriger, C. H. Blackman, W. B. Irwin, M. F. Mannion, R. L. Milner, F. N. Nye, W. E. Quinn, J. E. Teal, J. A. Schoch, L. K. Sillcox.

This is a progress report, presented as information.

The subcommittee plans to collaborate with the Mechanical Division, AAR, in revising the section of the Manual devoted to "Power" in order that the Engineering and Mechanical Divisions can more nearly agree on methods for computing locomotive characteristics.

The report on track capacity and train performance which was submitted last year as information is being prepared for inclusion in the Manual under the heading III Economics of Railway Operation. Before this is done, it has been decided to show the application to practical railway problems of some of the principles that are discussed in the report. For this purpose an exhibit has been prepared to show how the theory of train performance helps in comparisons and interpretations of operating statistics.

Briefly stated, the theory is based on the assumption that train performance can be divided into two parts; one part which is based on perfect performance can be predicted, the other part which is caused by imperfect performance cannot be predicted.

Given the profile, alinement and weight of trains, and the type and horsepower characteristics of the motive power, it is possible to calculate or determine by test the shortest road time or what may be regarded as perfect performance for these conditions, based on having a clear track. To effect a change in minimum road time or perfect performance, some change must be made in the given conditions. In practice, one or more but not many trains in a given test period of time will be found that perform perfectly.

The majority of trains that do not perform perfectly are generally improperly handled or are interfered with by other trains. The causes are too numerous to mention; hence the term interference or interference factor has been applied to that portion of train performance which is not perfect. That is, the difference between the average and minimum road time of trains is regarded as the average interference time per train. Theoretically, this average interference time depends upon the amount of traffic, that is, it is proportional to the number of trains operated in a given time, barring variations due to seasonal conditions.

The exhibit which follows demonstrates how statistics covering a wide range of conditions can be handled to show the effect of some of these conditions on the overall train performance and also their effect on the interference time.

An attempt is now being made to develop other exhibits in which the conditions do not vary over such a wide range, in order to demonstrate more conclusively how closely the theory applies in practice.

Incidentally, it is demonstrated that there is a direct relation between interference time and track capacity or apparent track capacity which explains the reason for connecting track capacity with train performance in the title of last year's report.

It is recommended that last year's report be consulted in connection with a study of the exhibit. Suggestions from those who read this report will be helpful and greatly appreciated by the committee in its work of developing this important but difficult subject for inclusion in the Manual.

Exhibit

The purposes of this exhibit are:

1. To show the application of the theory of train performance to actual cases.
2. To record actual performances to test the soundness of the theory.
3. To point out some of the steps that can be taken to extend and refine the theory.

In applying the theory of train performance to actual cases it sometimes happens that an opportunity is offered for checking parts of the theory against practice, but in general a search has to be made for instances where the conditions are suitable for this purpose. Then a great deal of work is required to compile the necessary statistics before a critical examination of the checks can be made. As a result these studies are seldom undertaken.

The following discussion attempts to show some of the steps that can be taken to harmonize widely differing performances by applying the theory to some of the basic conditions which produce characteristic performances that can be identified.

The cases described in this exhibit comprise a single-track line in mountainous territory and a multiple-track line in level territory. The multiple-track line is composed of two, three and four-track sections, but the four-track sections are short and unsuited for this discussion.

Performance data that are characteristic of operations on one, two and three-track lines have been obtained directly from train dispatcher sheets and are summarized in Table 1.

Data for the single track line cover a month's performance with automatic block signals (ABS) and train orders, also a month's performance after the centralized traffic control system (CTC) without train orders was installed in its place.

If care is used in selecting representative tests periods, a comparison of these data will show the overall effect of the change from ABS with train orders to CTC without train orders, which will be discussed later.

In the case of the multiple-track line the data cover 9 days' performances with automatic block signals and train orders for two and three tracks at two different periods, one in October 1941 and the other in October 1944, there being no changes in the signal system in the interim. The second period serves as a check on the first and is included for this purpose only.

On the three-track section two tracks are signaled for eastbound and only one track for westbound trains. On the two-track section each track is signaled for one direction only. The two and three-track sections are not adjacent—there being an intervening section—but the same trains operate over both sections, which means that the conditions are identical, that is, the necessity for making adjustments to correct for differences in train weight or type, or condition of motive power is eliminated.

In order for these data to be comparative the first step is to base the road times on equal distances (100 miles) and the number of trains on equal periods of time (9 days), as shown in Table 2.

The same data are also plotted in Fig. 1 to afford a visual comparison of performances under widely different conditions. The statistics taken by themselves plot as unrelated points; the theory supplies a basis for relating them. That is, the minimum road times are plotted along the horizontal axis and the average road times are plotted to correspond to the number of trains and the straight lines drawn through them.

Table 1.—Showing Actual Performance Data

	ONE TRACK	TWO TRACKS	THREE TRACKS	FULL DIVISION
MILES OF ROAD	125.3	57.61	44.13	133
MILES OF 2ND MAIN TRACK		57.61	44.13	133
MILES OF 3RD MAIN TRACK			44.13	NOT
MILES OF PASSING SIDINGS	21			REPORTED
NUMBER OF PASSING SIDINGS	25			
PROFILE	MOUNTAINOUS	LEVEL	LEVEL	LEVEL
TEST PERIOD	1 MONTH	9 DAYS	9 DAYS	9 DAYS
	JAN. 1944	OCT. 1–9, 1941	OCT. 1–9, 1941	OCT. 1–9, 1941
	APR. 1945	OCT. 4–12, 1944	OCT. 4–12, 1944	OCT. 4–12, 1944

ONE TRACK

		PASSENGER			FREIGHT		
		EASTBOUND	WESTBOUND	TOTAL	EASTBOUND	WESTBOUND	TOTAL
NO OF TRAINS A.B.S.	1944			346	251	269	520
C.T.C.	1945			287	268	280	548
HRS. ROAD TIME A.B.S.	1944			1249.4	1905.8	1808.6	3714.4
C.T.C.	1945			969.1	1488 4	1499.0	2987.4
MIN HRS ROAD TIME A.B.S.	1944			2.60	4.25	4.08	4.17
C.T.C.	1945			2.60	4.08	3.78	3.93

TWO TRACKS

NO OF TRAINS	1941	151	174	325	112	97	209
	1944	173	201	374	111	110	221
HRS. ROAD TIME	1941	147.01	154.91	301.92	183.95	155.64	339.59
	1944	172.23	188.13	360.36	220.81	197.44	418.25
MIN. HRS. ROAD TIME	1941	(3) 0.700	(4) 0.700	0.700	(2) 1.167	(1) 1.067	1.117
	1944	(1) 0.717	(2) 0.700	0.709	(1) 1.167	(1) 1.150	1.159

THREE TRACKS

NO OF TRAINS	1941	151	174	325	112	97	209
	1944	173	201	374	111	110	221
HRS. ROAD TIME	1941	100.82	110.12	210.94	143.78	124.46	268.24
	1944	113.24	130.52	243.76	145.33	157.06	302.39
MIN. HRS. ROAD TIME	1941	(3) 0.517	(1) 0.517	0.517	(1) 0.817	(1) 0.833	0.825
	1944	(2) 0.517	(8) 0.533	0.525	(5) 0.850	(1) 0.867	0.858

FULL DIVISION

NO OF TRAINS	1941	151	174	325			
	1944	173	201	374			
HRS ROAD TIME	1941	356.57	385.29	741.86			
	1944	418.98	463.33	882.31			
MIN. HRS. ROAD TIME	1941	(1) 1.78	(1) 1.75	1.77			
	1944	(1) 1.87	(2) 1.80	1.83			

NUMBERS IN ( ) INDICATES NUMBER OF TRAINS WITH THE MINIMUM TIME.

TABLE 2.—COMPARATIVE PERFORMANCES BASED ON 100-MILE TRIPS
9-Day Test Periods

ONE TRACK

		PASSENGER-			FREIGHT		
		EASTBOUND	WESTBOUND	TOTAL	EASTBOUND	WESTBOUND	TOTAL
NO OF TRAINS A.B.S.	1944			100.5	72.9	78.1	151.0
C.T.C.	1945			86.1	80.4	84.0	164.4
AVE. HRS. ROAD TIME A.B.S.	1944			2.89	6.060	5.366	5.700
C.T.C.	1945			2.70	4.433	4.233	4.350
MIN. HRS. ROAD TIME A.B.S.	1944			2.08	3.40	3.26	3.34
C.T.C.	1945			2.08	3.26	3.02	3.15

TWO TRACKS

NO OF TRAINS	1941	151	174	325	112	97	209
	1944	173	201	374	111	110	221
	AVE.	162	187.5	349.5	111.5	103.5	215
AVE. HRS. ROAD TIME	1941	1.691	1.545	1.607	2.851	2.785	2.820
	1944	1.729	1.625	1.673	3.454	3.116	3.284
	AVE.	1.710	1.588	1.645	3.150	2.961	3.059
MIN. HRS ROAD TIME	1941	1.215	1.215	1.215	2.03	1.85	1.94
	1944	1.245	1.215	1.230	2.03	2.00	2.02
	AVE.	1.230	1.215	1.222	2.03	1.93	1.98

THREE TRACKS

NO OF TRAINS	1941	151	174	325	112	97	209
	1944	173	201	374	111	110	221
	AVE.	162	187.5	349.5	111.5	103.5	215
AVE. HRS ROAD TIME	1941	1.514	1.434	1.471	2.909	2.907	2.908
	1944	1.484	1.471	1.477	2.966	3.236	3.101
	AVE.	1.497	1.454	1.474	2.938	3.082	3.007
MIN. HRS. ROAD TIME	1941	1.172	1.172	1.172	1.85	1.89	1.87
	1944	1.172	1.205	1.189	1.93	1.96	1.95
	AVE.	1.172	1.189	1.180	1.89	1.93	1.91

FULL DIVISION

NO OF TRAINS	1941	151	174	325	112	97	209
	1944	173	201	374	111	110	221
	AVE.	162	187.5	349.5	111.5	103.5	215
AVE. HRS. ROAD TIME	1941	1.775	1.665	1.716			
	1944	1.821	1.733	1.774			
	AVE.	1.800	1.701	1.747			
MIN. HRS. ROAD TIME	1941	1.338	1.316	1.331			
	1944	1.406	1.353	1.376			
	AVE.	1.372	1.335	1.353			

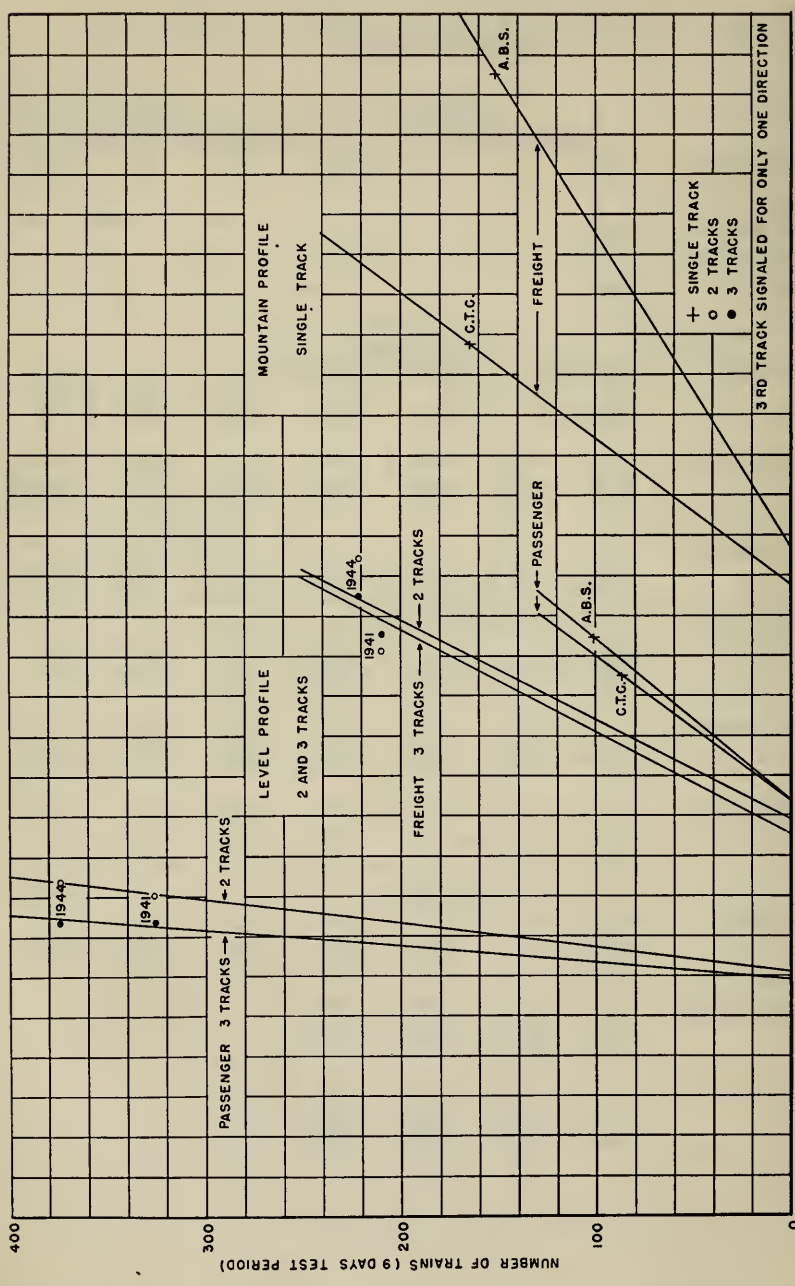


Fig. 1.—Comparative Train Performances, Passenger and Freight Trains on Level and Mountain Grades, Single and Multiple Tracks.

The minimum road times as explained previously represent perfect performances based on the profile and alinement of the line, the type and horsepower characteristics of the motive power and the weight of the trains. In these examples, they are observed times and may not agree exactly with the calculated or test results. For this reason it is sometimes necessary to adjust the observed minimum road times so that they will agree where they should agree; for example, in the case of passenger trains the minimum road times on two and three tracks should be the same if the profiles are identical.

The differences in the minimum road times between passenger and freight trains on level track are due primarily to the difference in weight of the two classes of trains and possibly to different classes of motive power, because the profile and alinement in both operations are identical.

The difference in the minimum road times in the case of passenger trains on single and double track can be attributed almost entirely to differences in profile and alinement of the two lines—one being mountainous and the other level. The same applies in the case of freight trains.

Other differences to be noted from the chart relate to the location of the lines and how they slope and other features which distinguish light from heavy traffic lines. Explanations of some of the reasons for these differences and what they indicate follow.

Comparison of Passenger Train Performance

Fig. 2 shows performance charts for eastbound and westbound passenger trains on the two and three-track sections as given in Table 2, in order to note the variations in the data obtained during the two periods. The bottom diagram is based on combining and averaging the data as given in the third column of Table 2.

In order to see how closely actual test comparisons support theoretical determinations it is necessary to refer to the theory as explained elsewhere and note a few places where the test performance do or do not agree with the theoretical. For example, if the profiles of all sections are identical then the same train if given a clear track would be able to make the same speed on all sections. That is, the minimum road times for 100 miles would be the same for one or two tracks as for three tracks.

Due perhaps to local conditions or experimental errors in the case of two and three tracks the minimum road times are not actually the same for both. If local conditions are the cause of the difference in road times, then an adjustment can be made for this difference by assuming that the solid line which represents the actual performance on three tracks is moved to the position shown by the dotted line, by making the minimum times for two and three tracks the same.

On this basis one way to compare the performances is to note the numbers of trains which correspond to a given average road time. Thus, for an average road time of 1.5 hours the corresponding number of trains is 220 for the two-track section, 320 for the three-track section, based on the dotted line, and 363, based on the solid line or actual performance on three tracks. The ratios of the number of trains are 1.0, 1.44 and 1.65, respectively.

By formula the potential track capacity of a three-track line is 3/2, or 1.5 times that of a double-track line, which checks very closely with the relative capacities found to be true in practice as shown above.

As a matter of interest the average road time of passenger trains on the single-track mountain grade line is also shown in the bottom diagram of Fig. 2 for comparison with the two and three-track level lines. Before a comparison can be made in this case between single and double track it is necessary to determine how much of the difference in performance is due to the difference in profile and how much is due to the difference in the number of tracks.

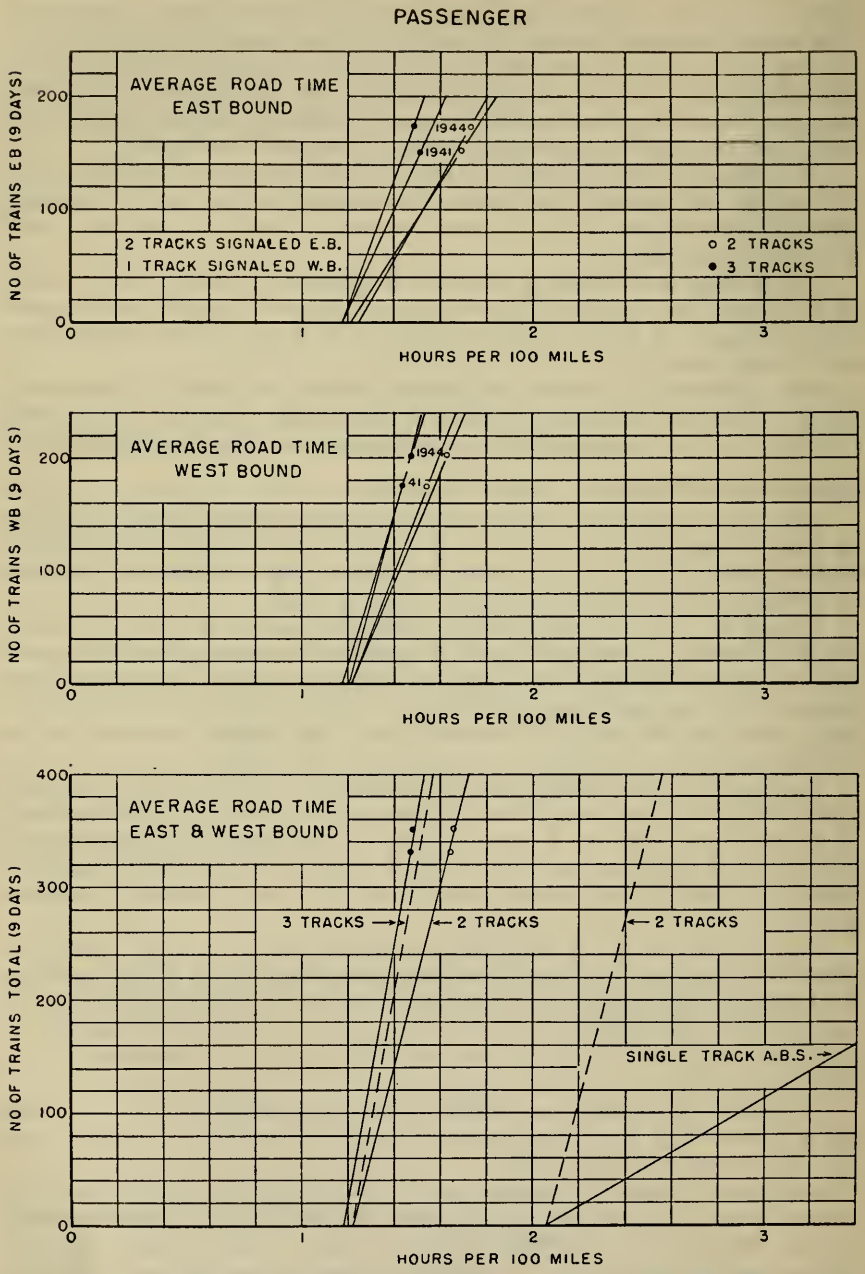


Fig. 2.—Effect of Multiple Track on Passenger Train Performance.

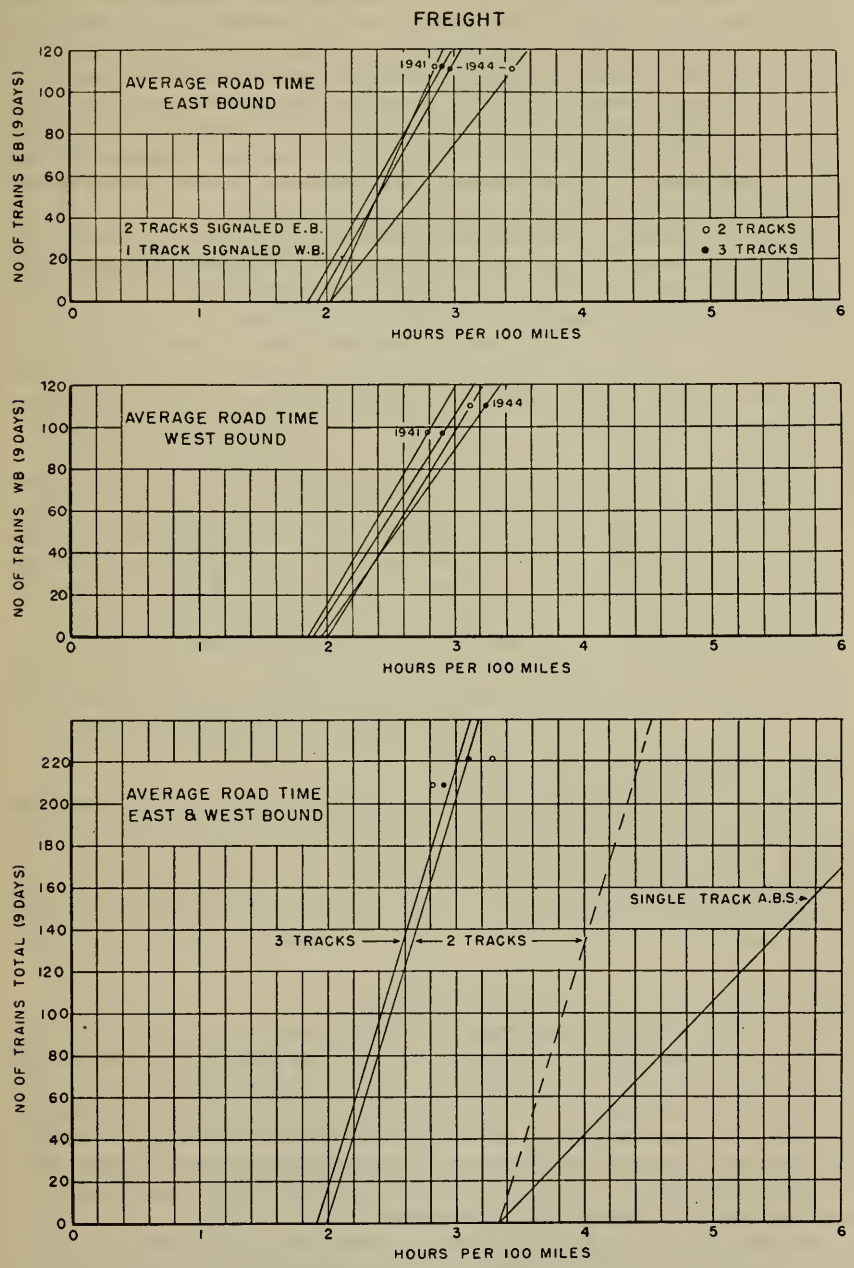


Fig. 3.—Effect of Multiple Tracks on Freight Train Performance.

It has been explained elsewhere that the minimum time represents the best time a train can make over a given profile, based on the characteristics of a definite type of motive power and on having a clear track. Thus, in this case it can be assumed that the characteristics of the motive power are essentially the same for single track as for double track, consequently the difference in the minimum road times is due to the difference in profiles. Thus, if the profile of the single track is level then its minimum road time will be the same as for double track or 1.22 hours instead of 2.06 hours. Or, conversely, if the profile of the double-track line is mountainous instead of level then its minimum road time will be 2.06 hours instead of 1.22 hours.

On the latter basis—in order to avoid confusion—the average road time of passenger trains on double track and mountainous grades for comparison with single track can be shown by drawing the dotted line through the minimum time of 2.06 hours, and parallel to the line corresponding to double track for level grade.

In order to compare performances note that the number of trains corresponding to 2.4 hours is 40 in the case of single track and 264 in the case of double track (dotted line), which indicates that the ratio of the number of trains is 6.6 for double track against 1.0 for single track.

Since the total length of passing tracks in the case of single track amounts to 21 miles, compared to 125 miles which would be the total length in the case of double track, the potential track capacity of the double-track line is approximately 125/21 or 6 times that of the single track line. Consequently it would be expected that the number of trains that could be operated over double track, based on a given average road time, would be 6 times the number which could be operated over a single track line having only 1/6 the capacity of double track and not 6.6 times as indicated by statistics.

There may be several causes which would account for the difference between the actual and theoretical comparisons in this particular instance. One reason, for example, may be the fact that the level track sections are equipped with track pans for scooping water, whereas on mountain grade lines this device for avoiding stops for water is impractical. Since water stops are frequently the cause of interference, this fact may account for the difference.

In this connection valuable data may be available in a number of instances where changes have been made from steam to electric or diesel power which will show the effect of other conditions upon the attainment of more dependable performance.

From the foregoing analysis it is clear that, based on automatic block signals with train orders, theoretical determinations of the effect of track capacity on passenger train performance are quite accurately supported in actual practice.

Comparison of Freight Train Performance

Fig. 3 shows the performance of freight trains on one, two and three tracks based on the use of automatic block signals and train orders. Referring to the eastbound and westbound charts it will be noted that in three out of four cases freight train performance on two tracks is apparently better than on three tracks, which is contrary to expectation. However, when the data for eastbound and westbound movements are combined as in the bottom diagram they show that freight train performance is slightly better on three tracks than on two, but not as much as would be expected from theory, or as shown in the case of passenger train performance.

The actual and theoretical comparisons of freight train performances do not agree in this case because the actual conditions are special and different from those on which the theory is based. For example in the actual case under consideration two tracks are signaled for eastbound and only one track for westbound trains, which produces unbal-

anced conditions in the case of freight trains, whereas the theory is based on balanced conditions in both directions.

It may be possible to balance the operations in both directions by signaling the third track for eastbound and westbound traffic. In this case there is reason to believe it will be found that theoretical relations will be closely supported in practice.

In the comparison of freight train performances on single and double track shown in the bottom diagram of Fig. 3 it will be noted that the number of trains corresponding to an average road time of 4 hours is 133 for double track and 42 for single track, which indicates that the apparent capacity of the double-track line adjusted for profile is 113/42 or only 3.17 times the capacity of the single-track line instead of being 6 times as determined previously, based on the relative potential track capacity of the two lines. Actually this is a misleading comparison and not a true test of the theory because of the fact that there are known differences in conditions in the two cases which have to be allowed for. From the statistics for double track there are about 3/2 as many passenger trains as freight trains whereas for the single track the statistics show the ratio is just reversed, there being only 2/3 as many passenger as freight trains.

The effect of this difference in the ratio of passenger trains to freight trains is considerable because passenger trains are likely to delay freight trains every time they meet or overtake them. On the other hand freight trains as a general rule delay each other only when they meet. Likewise in the case of passenger trains, seldom are they delayed by freight trains but they are likely to delay each other when they meet.

Thus, passenger train conditions closely approximate those pertaining to the operation of one class of trains. If the passenger trains in these examples wre eliminated then the freight trains could be operated under the same conditions, just one class of trains with about the same amount of interference as was found for passenger trains. That is, the freight and passenger performances could be represented by parallel lines on a chart. Support for this statement will be mentioned later in connection with an analysis of statistics relating to CTC signaling.

In all of the examples considered thus far, the type of motive power employed and the method of operation by automatic block signals and train orders are essentially similar. In some of the examples the profiles and traffic are practically identical, making it possible to compare theoretical and actual performances on an ideal basis. In other examples there is a wide difference in profiles and traffic. In these cases comparisons cannot be made on an ideal basis; adjustments have to be made for the differences in conditions. Any adjustments that have to be made lessen the confidence that can be placed in the comparisons unless the basis for the adjustments has some foundation in fact.

In other words, the best way to prove it is possible to estimate the effect of double tracking a mountainous grade line using data obtained from a level line, is to search for a double-track line with about the same profile as the single-track line and prove the truth or falsity of the estimate. It is for this purpose that more cases need to be studied in order to extend and refine the theory.

Effect of Signals on Train Performance

It will be seen from the preceding discussion that for a given average road time the number of trains that can be operated over a line is proportional to the track capacity. That is, when the train performance chart for a given track capacity is known the train performance corresponding to double the track capacity can be shown on the chart by doubling the number of trains or the ordinates of the chart. The reduction in average road time will be shown by the horizontal distance between the two lines corresponding to the given number of trains.

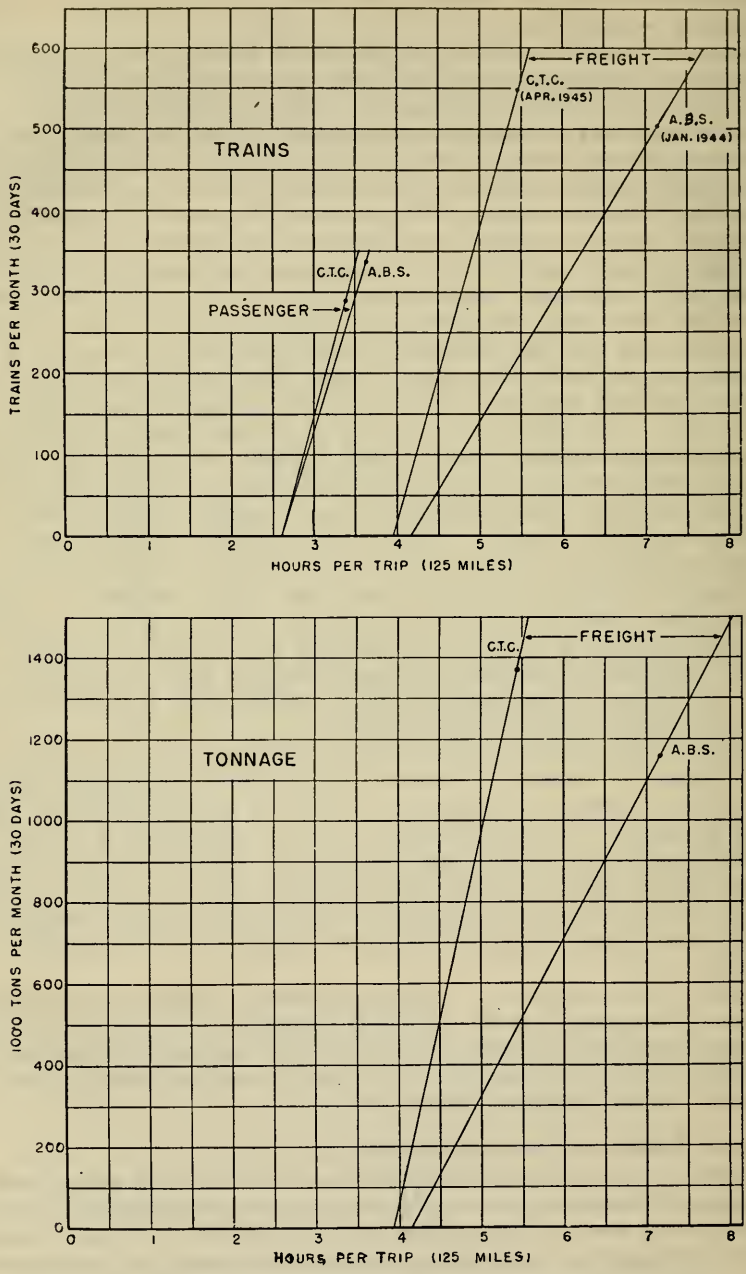


Fig. 4.—Comparison of Train Performances Based on ABS With Train Orders and CTC Without Train Orders.

The determination of the effect of signals on train performance is a different problem because there may be no change in the arrangement of tracks and, therefore, no change in track capacity. The problem involves a determination of how much time can be saved by one system over another by eliminating certain delays that are inherent in one system and not in the other. How closely the estimated reduction in delays agrees with the actual depends largely on experience.

Fig. 4 shows the application of train performance charts in a case where a study was made of statistics to determine the advantages of centralized traffic control (CTC) by signal indication without train orders over automatic block signals (ABS) with train orders. This comparison is based on a compilation of operating statistics for two representative test periods, January 1944 for ABS and April 1945 for CTC. The statistics were obtained directly from train dispatcher sheets and for the most part consist of a compilation of the weight of each train and its road time. Thus, when the compilations are completed the number of trains will be known, the shortest road time for any train can be picked from the lists, and the average road time and total tonnage handled can be determined. To avoid misleading comparisons it is extremely important to make sure that the periods selected are strictly representative.

After the comparative train performance chart is plotted it will usually be found that the number of trains and the tonnage handled are not the same in both periods. Consequently if it is desired to compare the average road times for ABS and CTC on the basis of the same number of trains, say 501 freight trains per month (30 days), the average road time is found to be 7.14 hours for ABS and approximately 5.32 hours for CTC, which is a reduction of 1.82 hours (109 min.) for a run of 125 miles.

If it is desired to compare the average road times on the basis of handling the same tonnage, say 1,156,000 tons per month (30 days), the average road time is found to be 7.14 hours for ABS and 5.21 hours for CTC as shown in the bottom diagram, or a reduction of 1.93 hours (115 min.), because heavier trains were handled after CTC was installed, consequently the same tonnage can be handled in fewer trains, that is in 462 trains instead of 501. (The number of trains corresponding to an average road time of 5.21 hours is 462 from upper diagram.)

Thus, train performance charts provide an easy way to adjust for unequal traffic when making economic comparisons on a common basis. In actual cases it is usually more satisfactory to consider the performance in each direction separately rather than together, so that different adjustments can be applied where necessary. Otherwise the procedure is the same.

Treating these statistics as typical of ABS and CTC, it is interesting to note that the number of trains corresponding to 5.5 hours is about 567 for CTC and 224 for ABS, which indicates that the track capacity apparently has been increased in the ratio of 567/224 or about 2.553 times. That is, the effect is the same as that which would be produced by increasing the track capacity 2.53 times.

Theoretically, the minimum road time based on increased capacity should be the same as for CTC, hence an adjustment should be made to correct this difference. This can be done by assuming that a line parallel to the ABS line is drawn through the minimum road time 3.93. In this case the number of trains corresponding to 5.5 hours will be 265. Thus the apparent increase in capacity will be in the ratio of 567/265 or 2.14 times.

Since the actual track capacity of the line is essentially the same for both signal systems or 1/6 of the track capacity of a double-track line (21/125) it means that the performance provided by CTC would be equivalent to that of ABS, on a line having (2.14 $\times$ 21) or nearly 45 miles of passing sidings in 125 miles instead of only 21 miles of passing sidings.

Similar statistics for ABS and CTC on lines where the amount of passing track is more than 1/6 or less than 1/6 of the length of the division would provide valuable data on the relative advantages of the two systems.

One of the most important points of theory which the CTC statistics demonstrate is shown by the fact that the passenger and freight train performance lines are nearly parallel, which is the result that would be looked for if only one class of trains were operated. Thus it would seem that CTC very nearly accomplishes this result, since it is possible to dispatch trains so as to give every one an even break.

For another illustration see Proceedings, Vol. 32, 1931, page 671.

Report on Assignment 3

Methods or Formulas for the Solution of Special Problems Relating to More Economical and Efficient Railway Operation

B. T. Anderson (chairman, subcommittee), E. Y. Allen, J. W. Barriger, C. W. Breed, H. S. Bull, J. L. Campbell, S. B. Clement, C. H. Fox, C. H. R. Howe, J. M. MacBride, R. C. Nissen, W. E. Quinn, W. T. Rice, B. J. Schwendt, H. M. Shepard, V. P. Turnburke, D. K. van Ingen, F. G. Walter, H. P. Weidman.

Your committee submits the following progress report as information.

The Renaissance of the Chicago, Indianapolis & Louisville Railway

The Chicago, Indianapolis & Louisville Railway, familiarly known as the "Monon," operates a 541-mile single track main line from Hammond, Ind., to Indianapolis and to Louisville, Ky., a single track branch line from Monon to Michigan City, Ind., a single track branch line from Orleans to French Lick, Ind., and a single track branch line from Wallace Junction to Midland, Ind. Passenger trains are operated over the Chicago & Western Indiana double track main line from State Line, 0.9 miles north of Hammond, Ind. to Dearborn Station, Chicago, Ill., a distance of 19.8 miles. The territory involved is shown in Fig. 1.

Since the railway was reorganized on May 1, 1946, the new management has undertaken an ambitious improvement program for rebuilding and modernizing its entire plant. These improvements include:

Complete dieselization by the end of 1947.
New passenger and freight cars.
New and heavier track structure and line changes.
Respacing automatic block signals and adding CTC.
Improved communication facilities.

A program requiring an estimated expenditure of 26 million dollars during the years 1947, 1948 and 1949 has been authorized of which 16 million dollars are for equipment and 10 million dollars for line and roadway improvements. An additional 24 million dollars may be spent in the following two years to round out the program which will make the Monon one of the more completely mechanized railroads in the United States.

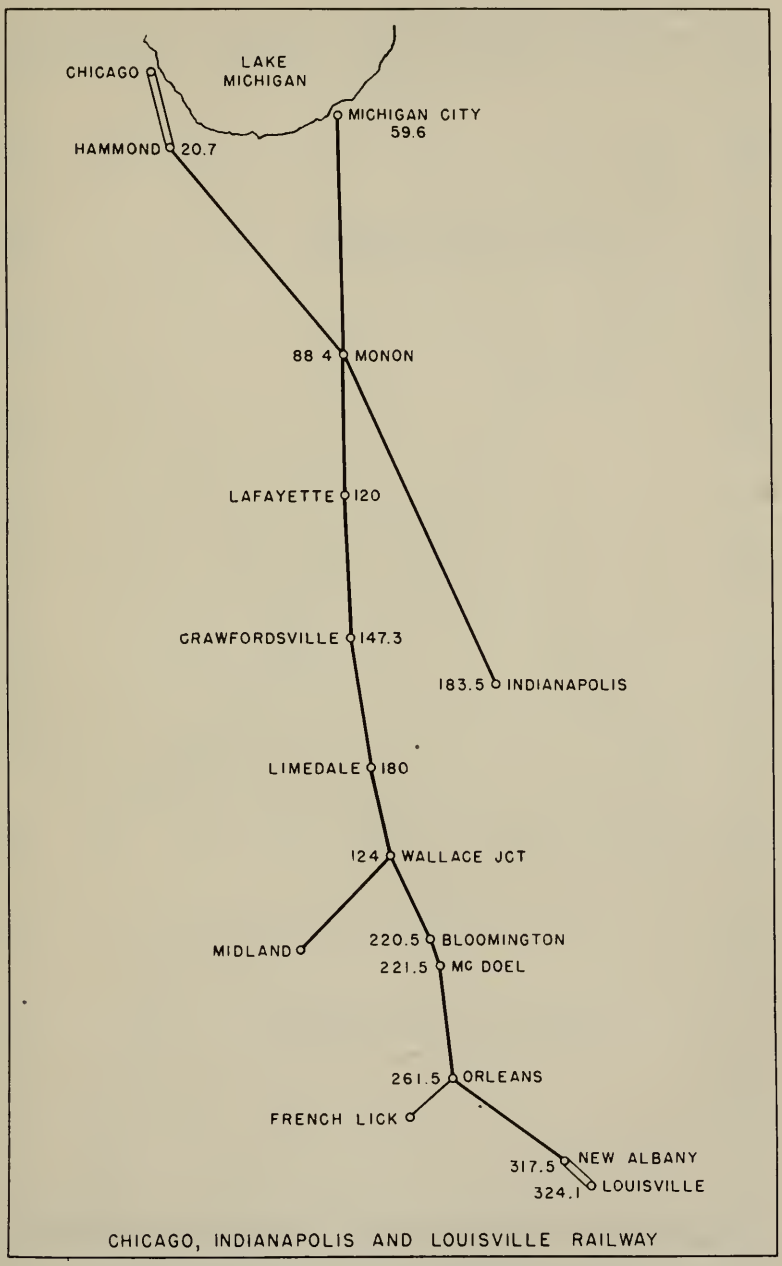


Fig. 1.—Diagram of the Monon Lines.

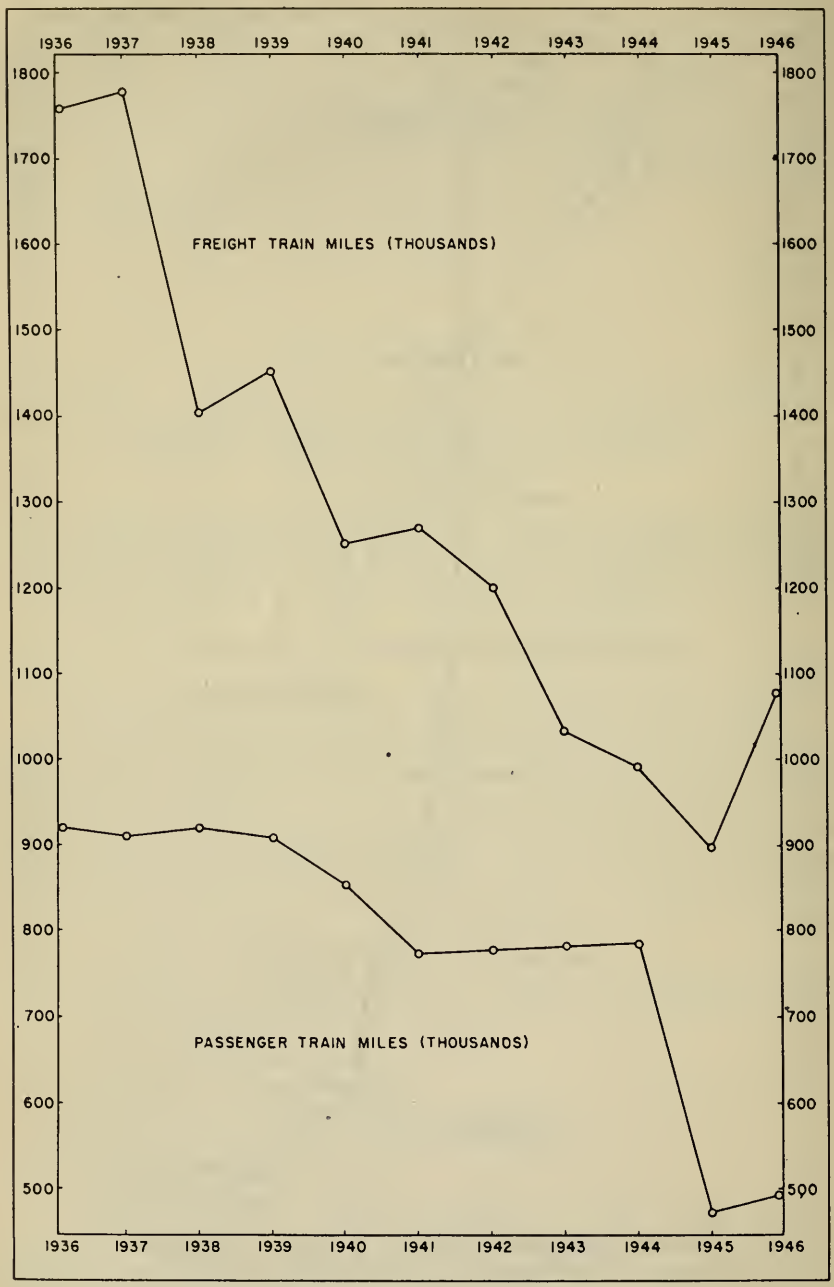


Fig. 2.—Freight Train and Passenger Train Miles, 1936–1946.

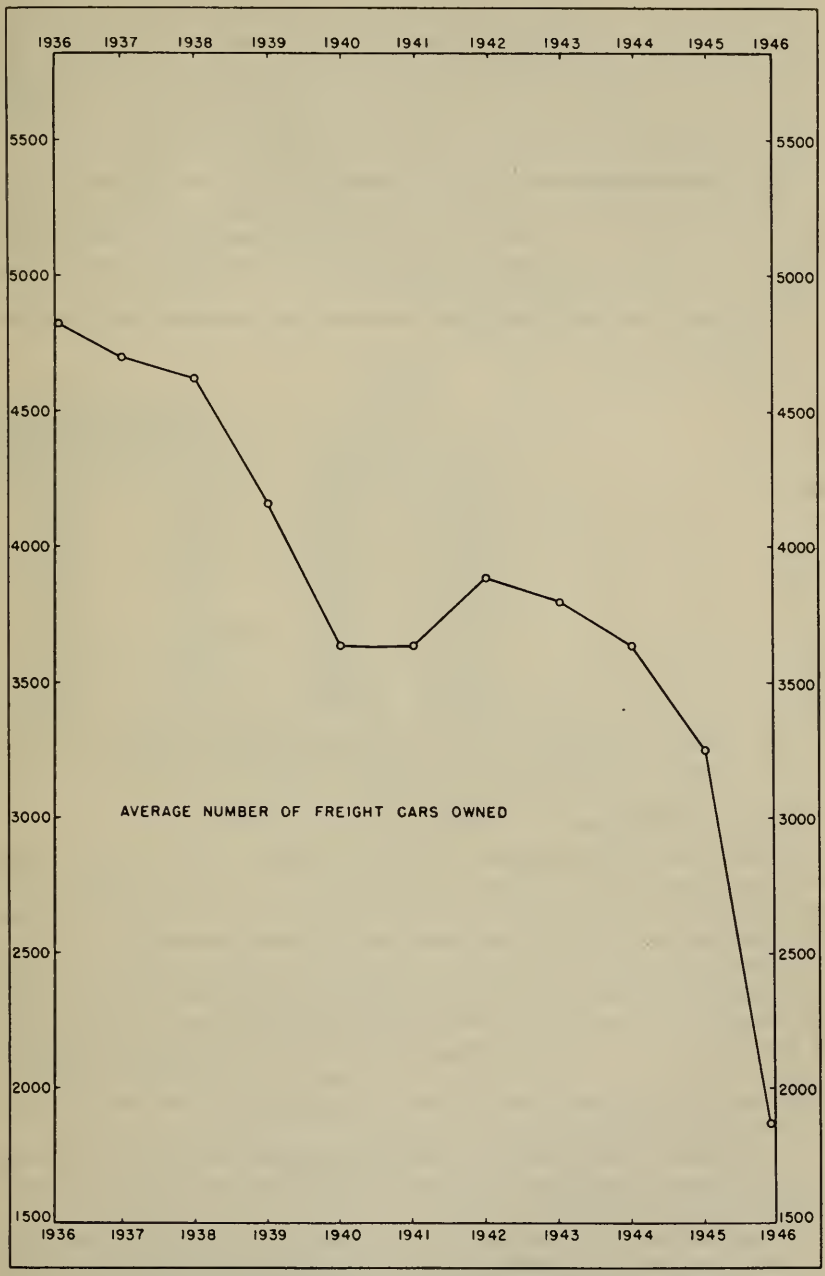


Fig. 3.—Average Number of Freight Cars Owned, 1936–1946.

A comprehensive modernization program of this type over an entire railway is of unusual interest to the AREA members. Committee 16, in connection with its meeting in June 1947, made an inspection trip over the Monon Raliway to develop first hand information of the property and the problems confronting its new management. It is proposed in this introductory report on the Monon to state briefly some of the aspects of the proposed program relating to motive power, equipment, track, signals and communications and to comment briefly on the present and anticipated results.

Prior to the reorganization in 1946, the Monon had deteriorated in plant and equipment. As a result, traffic sought other more expeditious means of transportation and freight and passenger service almost disappeared. The management was faced with either abandoning the line or embarking on a new program of revitalizing a property which celebrated its 100th birthday on July 7, 1947.

The revenue train-miles, freight and passenger, and locomotives and cars owned from 1936 to 1946 are shown in Table 1.

TABLE 1

	Revenue Train Miles		*Equipment Owned*	
Year	*Freight*	*Passenger*	*Locomotives*	*Freight and Company Cars*
1936	1,766,910	921,084	141	4,807
1937	1,785,109	916,991	135	4,706
1938	1,412,039	919,972	135	4,660
1939	1,451,506	910,451	127	4,202
1940	1,255,823	849,728	113	3,628
1941	1,275,414	770,331	97	3,639
1942	1,192,179	777,191	89	3,891
1943	1,040,518	777,698	89	3,802
1944	992,306	780,935	89	3,616
1945	899,842	460,188	88	3,241
1946	1,072,838	499,354	76	1,854

Figs. 2 and 3 show graphs of the freight and passenger train miles, and average number of freight cars owned from 1936 to 1946.

Description of Railway

The line between Hammond and Lafayette, 99.3 miles, crosses level prairie country with a maximum grade of 0.8 percent near Lafayette. The prevailing curves are 2 deg. with a maximum of 3 deg. 30 min., except for an 8-deg. curve at the Monon station. The ruling grade is 0.61 percent southward and 0.50 percent northward.

From Lafayette to New Albany near Louisville, 215.5 miles, the line passes through rolling hills with prevailing curves of 2 to 5 deg. with maximum curves of 5 deg. 40 min., except for an 8-deg. curve at the Crawsfordville station. The line from Hammond to New Albany is 75 percent tangent and 25 percent curves. The ruling grade from Lafayette to McDoel, 103.6 miles, is 0.64 percent southward and 0.88 percent northward while from McDoel to New Albany, 96 miles, the ruling grade is 1.25 percent southward and 1.50 percent northward.

From Monon to Indianapolis, 95.1 miles, the ruling grade is 1.0 percent southward and 1.08 percent northward with prevailing curves of 2 deg. and a maximum of 4 deg. This line is 87 percent tangent.

From Michigan City to Monon, 59.6 miles, the line is 96 percent tangent with a prevailing and maximum curvature of 30 min., and a grade of 0.69 percent southward and 0.4 percent northward. There is a 75-mile tangent between Michigan City and Brookston, about 18 miles south of Monon.

The main line, from Hammond to New Albany, is laid with 90, 100, 112 and 130-lb. rail, about 38 percent being 112 lb. and over, and 45 percent being 100 lb. The Indianapolis branch is mostly 90 lb. with almost 7 percent 100 lb. The Michigan City branch is laid with 75, 90 and 100-lb. rail, about 54 percent being 75 lb., 37 percent being 90 lb. and 9 percent being 100 lb.

Trains are governed by timetable, train orders and automatic block signals, except no block system is in use on the Michigan City branch. Maximum authorized speed is 75 mph. for passenger trains and 55 mph. for freight trains, except on the Michigan City branch where maximum speed is 25 mph.

Operating Subdivisions and Average Daily Traffic

The Monon operating Subdivisions and average trains daily, are as follows:

Location	*Sub-Division*	*Miles*	*Trains Daily Passenger*	*Freight*	*Total*
Chicago–Lafayette Shops	First	117.9	8	13.3	21.3
Monon–Indianapolis	Second	95.1	4	4.0	8.0
Michigan City–Monon	Third	59.6	0	4.0	4.0
Lafayette Shops–McDoel	Fourth	103.6	4	16.1	20.1
McDoel–Louisville	Fifth	102.6	6	14.3	20.3

The train count was based on three days in March 1947.

Proposed Improvements

Motive Power Program

As of May 1, 1946, the Monon owned 72 steam locomotives, averaging 27.4 years' age, and 4 diesel switch engines, averaging 4 years' age. Within a year, 29 of the steam locomotives had been retired and 15 new diesel locomotives purchased. The 72 steam locomotives, owned on May 1, 1946 included 13 Class K, 4–6–2, passenger locomotives, 54 Class E, G, H, J, & L, mostly Class J, 2–8–2, freight locomotives, and 5 Class B, 0–6–0, switchers with an average unit tractive effort for the 72 locomotives of 52,833 lb. The 43 steam locomotives, owned on May 1, 1947 had an average tractive effort of 52,756 lb. The 19 diesel locomotives, owned on May 1, 1947 had an average tractive effort of 63,142 lb.

The Monon, by the end of 1947, plans to have 37 diesel locomotives, which will be adequate to do the work of nearly twice that number of old steam locomotives. This change in motive power will permit the retirement of enginehouses, ash pits, coaling stations, water cranes and water treating plants over the system. The retired facilities will be replaced with new facilities at Lafayette for servicing the diesel power.

Equipment Program

On May 1, 1947 the Monon owned 34 passenger cars ranging from 3 to 54 years' age. It is proposed by the end of 1947 to retire 18 cars averaging 40.6 years' age and install 35 new cars to provide a total ownership of 51 cars by the end of 1947. The new cars are being converted from army hospital cars in the railway's own shops. On August 1, 1946, the Monon owned 2781 freight cars of which 1060 had been retired by May 1, 1947. One hundred forty-five additional cars will be retired in 1947. Seven hundred new freight cars will be delivered in 1947 and 450 additional cars will be ordered. The estimated ownership at the end of 1947 is 2276. The scheduled shop program includes heavy repairs and the conversion of 207 freight cars and the building 85 new freight cars.

The freight car ownership as of August 1, 1946, the estimated ownership as of December 31, 1947 and the estimated ownership as of December 31, 1949 are shown in Table 2.

TABLE 2.—STATUS OF FREIGHT CAR OWNERSHIP

(With changes therein from August 1, 1946 to May 1, 1947, and future program)

Type of Car	*Ownership at 8/1 46*	*12/31 46*	*5/1 47*	*Est. Retire-ments 1947*	*Orders Placed For Deliv-eries 1947*	*Est. Del. Date*	*Est. Owner-ship 7/1 47*	*Est. Owner-ship 12/31 47*	*Specs. Out For Quota-tions On*	*Est. Owner-ship 12/31 49*
Box	871	660	576	128	500	Start 5/47	1048	948	200	1248
Hopper	444	444	444		100	4th Quarter 1947	444	544		644
Covered Hopper	20	20	20		100	Start 7/47	20	120		120
Gondola Hi-side	751	59	15	15			15	0		300
Low side	468	428	427				427	427	200	395
Mill										50
Ballast	20	20	20				0	0		20
Flat	145	77	72	2			72	70		120
Stock	15	1	0				0	0		25
Coke	47	45	40				40	40		55
Quarry to mill	0	100	107				107	107		110
Total	2781	1854	1721	145	700		2193	2276	400	3087

Roadway Program

The three-year program includes the following items:

Title of Project	*Gross Cost*
1947	
Line changes at two locations	$1,430,000
Roadway machines and grading equipment	194,400
Relay 112-lb. rail	634,000
Deisel repair shops	266.000
Mcle. R. & E. work*	300.000
Total	$2,824,400
1948	
Line changes at seven locations	$ 759,350
Freight house change	230,000
New 112-lb. rail	1,268,000
Mcle. R. & E. work	300,000
Total	$2,557,350

* Relocating and extending passing tracks; modernizing stations; rebuilding bridges; modernizing roadway and shop buildings; roadbed widening; flasher signals, etc.

Title of Project	*Gross Cost*
1949	
Line changes at three locations	$1,545,000
New 112-lb. rail	1,268,000
Mcle. R. & E. work	300,000
Total	$3,133,000
Total, 1947–1949	$8,494,750

Signal Program

The three year program includes the following items:

Title of Project	*Gross Cost*
1947	
Six new interlockings	$ 104,000
1948	
Two new interlockings	$ 10,000
Respace and improve signals	407,000
CTC	300,000
Total	$ 717,000
1949	
Respace and improve signals	$ 237,500
One new interlocking	12,400
CTC	150,000
Total	$ 399,900
Total, 1947–1949	$1,221,300

Communications Program

The 1947 program includes additional telephone facilities estimated to cost $171,000.

Progress of Modernization Program

The three year roadway, signal and communication program includes a total cost of $9,887,050 of which about $6.000,000 is chargeable to Road and Equipment.

The 1947 program is actively underway and satisfactory progress is being made on the motive power, car, roadway, signal and communication improvements.

Diesel operation is estimated to save about 30 percent on locomotive maintenance and shop costs and has aided in reducing the operating ratio. All scheduled passenger trains are diesel operated and all scheduled freight service, except on the Michigan City branch, has been dieselized with savings in road and crew time. Diesel operation of the freight trains, as on other railroads, has shown the necessity for a modern track, signal and communication plant.

The roadway program is proceeding as fast as material, labor and plans are available and includes, in addition to 42 miles of 112-lb. rail, the addition of 76,000 new treated ties. The signal improvements at the six interlockings are under way or in process of agreement with the various interested railroads. The communication improvements provide additional telephone lines and the substitution of telephone for telegraph dispatching on certain sections of the line.

General business conditions on the railway have improved since its organization May 1, 1946. Cars loaded and received are up over 100 cars a day and now total approximately 535 daily. The Monon gross revenue for the first quarter of 1947 was 47.9 percent larger than for the same period in 1946.

The gross revenue in recent years has been as follows:

Year	*Gross Revenue*
Average 1937–1946	$10,845,000
Peak year, 1944	13,490,000
1945	11,556,500
1946	11,457,996
Estimated 1947	15,200,000

Conclusion

The Monon's modernization program contemplates:

Improved service to the shippers and traveling public.
Increased freight and passenger train speeds.
Heavier train loading.
Fewer and longer sidings, 1.5 to 2.0 miles in length with long turnouts, sidings spaced 8 to 13 miles apart.
Improved track structure and line changes to reduce grades and flatten curves.
Modern stations and improved roadway buildings.
Improved signaling with signal indication operation and increased protection at nonprotected railway grade crossings.
Improved telephone service.

While sufficient time has not yet elapsed, to report the ultimate effect of the improvements, the committee intends to follow the matter further and report in succeeding years the results of this program on the Monon railway.

Report on Assignment 5

Electrification and the Development of Modern Power Units; Their Influence on Railway Economics

Collaborating with Electrical Section, Engineering Division, and Mechanical Division, AAR

L. K. Sillcox (chairman, subcommittee), E. G. Allen, J. W. Barriger, C. H. Blackman, C. W. Breed, H. S. Bull, S. B. Clement, Spencer Danby, Miss Olive W. Dennis, Benjamin Elkind, G. W. Hand, W. B. Irwin, E. E. Kimball, F. H. McGuigan, Jr., H. J. McKenzie, P. E. Needham, R. C. Nissen, F. N. Nye, J. F. Pringle, W. T. Rice, R. W. Rogers, E. H. Roth, J. A. Schoch, H. F. Schryver, H. M. Shepard, H. W. Snyder, H. D. Walker.

Your committee submits as information, the following report on the electrification and the development of modern power units; their influence on railway economics. This report comprises a compilation of data submitted by a group of railways presenting comparative data for steam and diesel motive power, and covering discussion. While only summarized data are included in this report, your committee has complete supporting material in its files.

Request was made that, wherever possible, the submitted reports be given in train-miles for passenger service, 1000 gross ton-miles for freight service, and locomotive-

TABLE 1.—PERCENTAGE INCREASE IN STEAM LOCOMOTIVE REPAIR COSTS

Railway	Tractive Effort	Period	Number Years	Number Locomotives	Locomotive-Miles	Train-Miles	Car-Miles	Percent Increase
Switching Service								
C	54,000	1936–46	10	8	2,304,410			100.5
A	61,400	1936–45	9	40	15,884,000			99.5
B	45,500	1936–45	9	91	21,098,000			106.2
Total				139	39,286,410			103.9
Freight Service								
A	75,900	1936–46	10	25	11,498,000			91.4
A	142,000	1936–44	8	16	5,270,000			103.8
A	104,200	1936–45	9	25	9,308,000			50.6
C	71,800	1936–46	10	26	26,751,870			98.0
Total				92	52,827,870			84.3
Passenger Service								
A	57,580	1936–46	10	28	20,416,000			47.8
A	58,300	1936–44	8	13	10,193,000			50.8
B	62,000	1936–44	8	49	26,491,000			46.4
C	55,000	1938–46	8	9		10,831,511		638.0
Total				99	57,100,000	10,831,511		101.2
GRAND TOTAL				330	149,214,280	10,831,511		97.7

TABLE 2.—PERCENTAGE INCREASE IN DIESEL LOCOMOTIVE REPAIR COSTS

Railway	Hp.	Period	Number Years	Number Locomotives	Locomotive-Miles	Locomotive-Hours	Percent Increase
Switching Service							
D	360	1941–44	3	5	585,240		250.0
D	600	1937–46	9	24	10,335,408		94.0
B	600	1936–44	8	6	1,236,429		98.7
A	600	1939–45	6	5	1,220,000		90.8
A	1000	1939–46	7	49	12,069,000		180.0
D	1000	1940–46	6	84	23,689,680		316.0
E	380	1942–45	3	3		61,384	296.0
F	600	1937–46	9	1		56,520	627.0
E	600– 660	1942–45	3	23		516,386	55.5
G	660	1942–45	3	12		287,125	89.5
H	660	1940–44	4	4		122,850	736.0
G	1000	1943–46	3	4		96,309	190.0
H	1000	1940–46	6	3		133,172	1330.0
E	1000	1942–46	4	93		2,473,289	85.0
I	600–1000	1940–46	6	41		1,487,387	260.0
J	660–1000	1942–46	4	35		576,408	140.5
K	All	1938–45	7	141		3,377,211	198.0
Total				533	49,135,757	9,188,041	203.0
Freight Service							
A	2700	1941–44	3	14	336,000		95.5
A	4050	1941–44	3	18	187,000		283.0
A	5400	1943–46	3	60	3,788,000	1000 GTM	6.4
I	5400	1942–45	3	6		7,871,148	169.0
K	5400	1942–45	3	79		46,711,522	58.1
J	2700	1942–46	4	22		21,833,802	38.6
Total				199	4,311,000	76,416,472	66.6

TABLE 2.—PERCENTAGE INCREASE IN DIESEL LOCOMOTIVE REPAIR COSTS, Continued

Railway	Hp.	Period	Number Years	Number Locomotives	Locomotive-Miles	Train-Miles	Car-Miles	Percent Increase
				Passenger Service				
G	4000	1942–46	4	8	6,606,600			135.5
B	2000	1941–44	3	5	4,490,940			164.5
I	3600–4000	1937–44	7	22	15,922,982			99.0
K	2000	1940–45	5	15		14,149,153		290.0
D	1800	1936–42	6	2		3,848,466		417.5
D	3000	1936–43	7	2		4,774,020		445.0
D	4000	1940–44	4	15		16,453,005		233,0
C	4000	1939–46	7	2		3,068,456		685.0
J	2000	1939–45	6	38			153,745,326	22.2
Total				109	27,020,522	42,293.100	153,745,326	145.6
GRAND TOTAL				841	80,467,279	42,293,100	153,745,326 76,416,472—1000GTM. 9,188,041—Locomotive Hours	163.3

hours for switching service. However, several railways did not have data available in these forms, rendering comparison difficult. For example, diesel passenger locomotive data were submitted on a locomotive-mile basis by four roads, on a train-mile basis by five roads, with one submission being on a car-mile basis.

The fact that the ages listed are averages should be stressed. That is to say, the entire groups were not purchased simultaneously, but individual units were added from time to time.

While no attempt to reach reliable conclusions from the answers to the submitted questionnaire should be made in the absence of all essential pertinent supporting material, your committee is in a position to present herewith data relative to the effect of age on locomotive repair costs. The effort was surrounded with questions which must be answered before derived values can be taken as absolute, and, for that reason, arbitrary standards were set up and respected in every instance when preparing Tables 1 and 2. Diesel locomotives for which repair cost data applicable to less than three years' service were not included, and in the case of steam locomotives a minimum of eight years was required for inclusion.

To base the derived values on the entire span of submitted data for a given locomotive would in some instances result in a decreasing cost with age, and to avoid recording data which were known not to be indicative of experience the high year was selected on the assumption that heavy repairs were made in that year, thus again reducing the annual charge to this account. An example is a fleet of 4050-hp. diesel freight locomotives for which the following values were submitted.

Year	*Cost in Cents Per Locomotive-Mile*
1941	15.58
1942	25.17
1943	28.48
1944	59.72
1945	14.98
1946	15.55

It will be noted that a slight decrease, 1946 from 1941, obtains; also, that the 15.58 cents value for 1941 increased annually until a high of 59.72 cents is shown in 1944, following which the cost dropped and remained below the 1941 figure. In this, as all such cases, the period 1941 to 1944 was used.

Some very high increases were submitted but they are included in the summary in the absence of authority relative to limiting factors. Examples are a group of 1000-hp. diesel switching locomotives, where the cost rose from 15.6 cents per locomotive hour in 1940 to 223.2 cents in 1946, an increase of 1330 percent. Very decided and erratic increases from year to year were indicated, but in the case of a series of steam passenger locomotives the annual increase was comparatively gradual, as will be noted below, although an overall percentage increase of 638 results:

Year	*Cost in Cents per Train-Mile*
1938	6.26
1939	8.71
1940	15.77
1941	14.41
1942	19.09
1943	22.56
1944	30.08
1945	42.51
1946	46.23

In most instances the final results are not too greatly affected as the number of locomotives is quite large, but the inclusion of these locomotives raises the percentage increase of steam passenger locomotives from 47.5 to 101.2.

Further influencing factors which have not been evaluated are the marked increases in labor rates and material prices. These increases must be considered in a quantitative examination of the effect of age on repair cost.

Bearing in mind these qualifying factors, explanation for which was not available at the time report was prepared, the following percentage increases have been derived:

Percentage Increase in Locomotive Repair Costs

	Per Cent	**Avg. Age Years*
Steam: (8 to 10-year periods)		
Passenger	101.2	20.0
Freight	84.3	18.0
Switching	103.9	30.1
Total	97.7	25.2
Diesel: (3 to 9-year periods)		
Passenger	145.6	5.0
Freight	66.6	2.3
Switching	203.0	4.0
Total	163.3	3.9

* Age data incomplete.

Reference to the rates applied in determining fixed charges develops a wide range of percentages, in that depreciation varies from a low of 2.83 to a maximum of 3.32 for steam power and from 3.88 to 6.6 for the diesel inventory; also that interest charged ranges from 1.5 to 6 percent, while insurance rates and taxes are various.

As has been true with all steam-diesel data made available to the subcommittee, it is necessary to compare relatively new diesel locomotives with old steam power. However, while there is a discrepancy in the ages of the locomotives, the comparison covers the actual motive power being used by the railways at this time so that a policy may be established and decisions reached based upon the showing made in current practice. It appears to be a more reliable and determinative index than any that could possibly be obtained by estimates.

This report is submitted as information with the recommendation that the subject be continued in order that more complete data of a similar character may be collected, thus providing a more comprehensive basis for decisions as to the economic justification of the two types of power.

Report on Assignment 6

General Course of the Cost of Railway Transportation and Operation over the Past 100 Years; Principal Determining Elements and Economic Significance

R. L. Milner (chairman, subcommittee), E. Y. Allen, V. T. Boughton, W. E. Chapman, Miss Olive W. Dennis, C. H. Fox, C. H. R. Howe, H. W. Jensen, Fred Lavis, M. F. Mannion, C. P. Richardson, R. W. Rogers, E. H. Roth, A. L. Sams, H. M. Shepard, H. W. Snyder, J. E. Teal, F. G. Walter, H. P. Weidman, J. A. Wood, J. S. Worley.

Your committee submits the following progress report as information, and recommends that the subject be continued.

Foreword

The title of this assignment reveals a subject of vast proportions. It might be interpreted to cover practically all phases of railway transportation and operation, plus an endless number of related subjects. It has political as well as historical aspects. It could be construed to include countries other than the United States. If fully developed, it would attain voluminous proportions, on which a well staffed organization could be engaged in exhaustive research for an indefinite period.

This was discussed by Committee 16 at the meeting held in September 1946, at Chicago. At that time, after the reading of a brief outline, which depicted the vast scope of the subject, the committee, realizing the impracticability of fully developing the assignment, decided that a condensed report was desirable; that is, one that would touch briefly on the three phases of the subject as assigned. The study is confined solely to the railroads of the United States.

The word "cost," as used in this report, is considered as a cost of production, or a cost of supplying transportation or service, rather than the cost to the public or receivers of freight and passenger service. The latter would involve rates, with all the many ramifications and intricacies.

One factor which limits the extent of the report is the lack of comparative data covering the costs of transportation and operation of railroads as a whole during the period of their early development.

In limiting the scope of the report, consideration was given to some of the principal subjects covered by the broad title, and for this purpose, the following outline, which is a practical restatement of the title, was developed. This was done more for the purpose of indicating the range of the subject, rather than as a guide to follow for the report. It is necessarily brief and can be greatly expanded.

The Cost of Railway Transportation and Operation in the Past 100 Years

I. The General Course.

A. Statistics—Charts.

1. Traffic units.
2. Operating expenses.

a. Total.

b. Per 1000 traffic units.

1. In dollars of current value.
2. In dollars of 1926 purchasing power.

II. The Principal Determining Elements.

A. Interest Expense.

1. Investment—capital expenditures.

a. Road.
b. Equipment.
c. General.

B. Operating Expenses.

1. Maintenance of way and structures.
2. Maintenance of equipment.
3. Traffic.
4. Transportation.

C. Other Influences on Cost.

1. Wages.
2. Wholesale prices.
3. Personnel matters.
4. Population increase.
5. Geographical influence.
6. Natural resources.
7. Agricultural development.
8. Industrial development.
8. Competitive transportation agencies.
10. Influence of wars.
11. National income influence.
12. Federal policy.
13. Mergers and consolidations.

III. The Economic Significance.

A. General Prosperity.

1. Volume of business.
2. Competitive agencies.
3. Maximum utilization of plant.

a. Solicitation of business.
b. Location of industries.

4. Reduction of overheads.
5. Increasing economy.
6. Equality of treatment of all transportation agencies.

Under each of the headings given it is obvious that there would be a myriad of subheadings in any fully expanded outline, such as would be necessary for a full report.

As a simple illustration, all of the accounts under operating expenses may be broken down as to freight and passenger. In like manner, they may be broken down into labor and material and other expenses. The subject of federal policy may be divided into studies of the influence of the Interstate Commerce Commission, taxes, the eight-hour law, pension laws, subsidy of competitive transportation agencies, and so on.

This possible breakdown and expansion of any of the chief headings mentioned in the outline shows the necessity of treating the entire report in a general, rather than a specific and detailed manner.

TABLE 1

TRAFFIC UNITS, OPERATING EXPENSES OF STEAM RAILWAYS IN THE UNITED STATES, 1890-1945 (c)

Year ended	Traffic units* (thousands)	Operating expenses (thousands)	Operating expense per 1000 traffic units: Current dollars	Operating expense per 1000 traffic units: Dollars of 1926 purchasing power
June 30, 1890	111,750,405	$ 692,094	6.19	a 13.04
1891	119,606,516	731,888	6.12	a 13.65
1892	128,329,744	780,998	6.09	a 13.64
1893	136,275,415	827,921	6.08	a 13.68
1894	123,203,443	731,414	5.94	a 13.48
1895	121,792,854	725,720	5.96	a 13.59
1896	134,475,381	772,989	5.75	a 13.23
1897	131,909,842	752,525	5.70	a 13.17
1898	154,217,366	817,973	5.30	a 12.35
1899	167,441,241	856,969	5.12	11.91
1900	189,710,779	961,429	5.07	11.52
1901	199,137,900	1,030,397	5.17	11.49
1902	216,359,184	1,116,249	5.16	11.22
1903	235,968,571	1,257,539	5.33	10.88
1904	240,291,732	1,338,896	5.57	11.60
1905	257,863,557	1,390,602	5.39	11.23
1906	291,379,274	1,536,877	5.27	10.54
1907	319,757,052	1,748,516	5.47	10.52
1908	305,630,066	1,710,402	5.60	11.20
1909	306,130,956	1,650,034	5.39	10.91
1910	352,032,403	1,881,879	5.35	10.26
1911	353,388,782	1,976,332	5.59	10.37
1912	363,477,807	2,035,058	5.60	10.31
1913	405,748,346	b 2,235,923	b 5.51	b 9.86
1914	394,708,705	2,280,416	5.78	10.18
1915	374,559,585	2,088,683	5.58	9.73
Dec. 31, 1916	471,833,222	2,426,251	5.14	8.34
1917	518,562,336	2,906,283	5.60	7.73
1918	538,415,435	4,071,522	7.56	8.90
1919	507,675,869	4,498,817	8.86	9.05
1920	555,808,467	5,954,394	10.71	9.45
1921	422,650,576	4,668,998	11.05	10.94
1922	449,620,674	4,509,991	10.03	10.59
1923	531,138,084	4,999,383	9.41	9.76
1924	501,049,907	4,608,807	9.20	9.52
1925	525,919,383	4,633,497	8.81	8.88
1926	554,461,814	4,766,235	8.60	8.60
1927	535,407,241	4,662,521	8.74	8.91
1928	531,239,445	4,508,606	8.49	8.75
1929	543,681,611	4,579,162	8.42	8.68
1930	466,442,302	3,993,621	8.56	8.80
1931	376,872,672	3,273,906	8.69	10.11
Dec. 31, 1932	286,300,799	2,441,814	8.53	11.05
1933	299,755,319	2,285,218	7.62	10.43
1934	324,497,446	2,479,997	7.64	10.09
1935	339,165,549	2,630,177	7.75	9.99
1936	408,560,939	2,973,366	7.28	9.29
1937	436,901,024	3,165,154	7.24	8.92
1938	356,837,164	2,762,681	7.74	9.71
1939	403,514,309	2,959,438	7.33	9.33
1940	446,815,512	3,131,598	7.01	8.84
1941	565,794,982	3,709,921	6.56	7.88
1942	802,233,327	4,653,705	5.80	6.29
1943	993,907,262	5,714,804	5.75	5.88
1944	1,027,573,595	6,345,035	6.17	6.21
1945	959,627,507	7,115,391	7.41	7.29

a - Partially estimated.
b - Class I and II railways only.
c - Intercorporate duplications not excluded. Except where otherwise noted, the figures cover railways of Classes I, II and III, subject to the general exception that beginning with 1908 the returns for switching and terminal companies have not been included, while before that year they were.
* - Traffic units - one revenue ton mile is counted as one traffic unit; one passenger mile is counted as three traffic units.

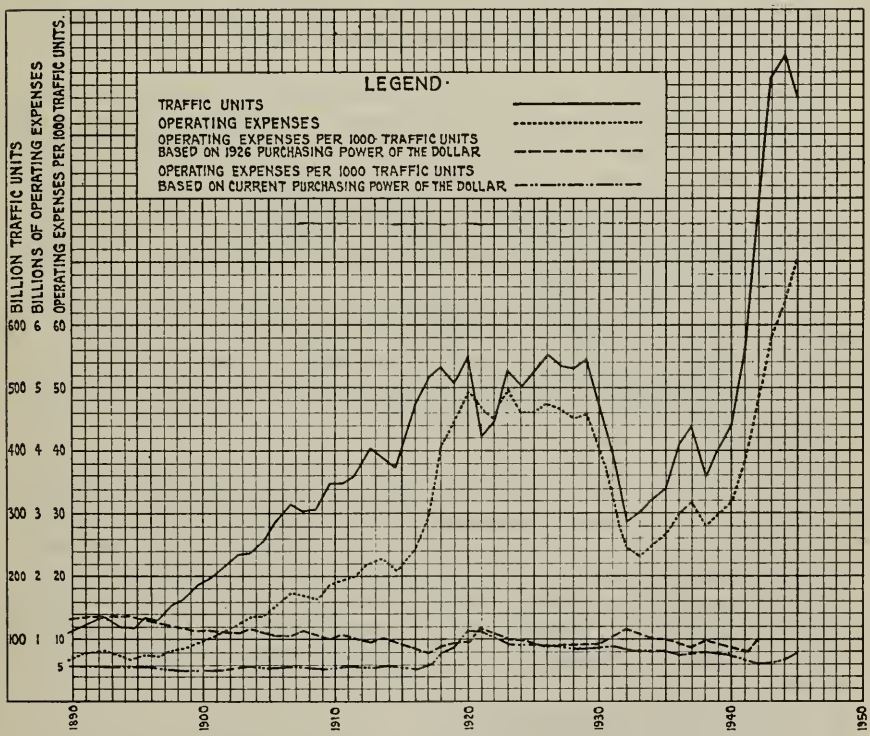
The General Course of the Cost of Railway Transportation and Operation in the Last 100 Years

It has thus far not been possible to develop any statistics as to operating and transportation costs for the railroads of the United States as a whole prior to 1890, although Poor's Manual of Railroads provides some cost data as far back as 1871. Other statistical data are available as far back as 1840.

In order to portray the general course of the cost of railway transportation and operation, Table I was prepared to show, from 1890 and on:

1. Total number of traffic units per year. (Traffic units represent the sum of revenue ton miles plus passenger miles multiplied by three.)
2. Operating expenses of steam railways of the United States.
3. Operating expenses per 1000 traffic units—
   a. In dollars of current purchasing power for each year;
   b. In dollars of 1926 purchasing power.

A chart has been made up to show this same information graphically.



Traffic Units and Operating Expense

The term "current year" or "current dollar," in the report, applies to the dollar of any year selected. For instance, in 1932 the operating expense per 1000 traffic units, as shown in Table 1, amounted to 8.53 dollars of 1932 purchasing power. It would have taken 11.05 dollars of 1926 purchasing power to meet the same expenses in 1932.

The ratio between constant dollars and current dollars is the ratio of current realized national income for any year to the national income for that year, based upon the constant dollar of 1926 purchasing power. The use of the 1926 dollar in this report as the "constant" dollar was based on the income figures from the National Industrial Conference Board.

It can be seen from the statistics that railroad operating expenses, in terms of the constant dollar of 1926 purchasing power, showed a steady decrease, from $13.04 per 1000 traffic units in 1890 to $7.73 in 1917, or a 41-percent decrease. During this same period the number of traffic units increased from 111.8 billion to 518.6 billion, or 364 percent. Then, despite the fact that the volume showed an overall increase from 1917 to 1920, the unit cost increased—primarily because of war conditions and increased costs of material and wages. A sharp decrease in the volume of business, of 133.2 billion traffic units, 24 percent, occurred during the depression of 1921. This was parallelled by an increased unit cost of 19 percent.

This was followed by an upturn in business, from 422.7 billion units in 1921. Then, after reaching a high, in 1926, of 554.5 billion traffic units, ended, in 1926, at 543.7 billion units, for an increase of 29 percent. The unit cost of railroad transportation and operation decreased from $10.94 in 1921, to $8.68 per 1000 traffic units in 1929, or 22 percent.

From 1929 until 1932, at the bottom of the depression of that period, traffic volume decreased from 543.7 billion units to 286.3 billion units, or a decrease of 257.4 billion traffic units, or 47 percent. At the same time the unit cost increased from $8.68 to $11.05 per 1000 traffic units, or 27 percent.

From 1932 until 1937, traffic volume increased 150.6 billion units, or 53 percent, while unit cost decreased from $11.05 to $8.92, or 19 percent.

The year 1938 reflected a short but sharp reduction in business volume of 18 percent, and unit costs increased 9 percent.

From 1938 and on through the war period, business volume experienced tremendous increases, reaching a high at 1027.6 billion traffic units in 1944, an increase of 188 percent, and receding but slightly in 1945. At the same time, unit costs decreased to $7.88 per 1000 traffic units in 1941, beyond which, data are not yet available. It should be remembered that during the period beginning with 1941, wages and material costs increased greatly.

Thus unit costs, based on the 1926 purchasing power of the dollar, have decreased 40 percent since 1890 to 1941, whereas traffic volume increased 406 percent. This indicates that unit costs have decreased in much smaller proportion than the increased volume of transportation would seem to warrant. This may be explained in part by the increased costs of labor and material, two factors which have greatly increased since 1941. This stresses the necessity of controlling these costs as far as possible, as the effect of the increased costs since 1941 would be most noticeable should there be an appreciable recession in volume of transportation. It shows the importance of control of ovehead expenses.

The Principal Determining Elements

The principal determining elements of the cost of railroad transportation and operation go beyond the simple item of operating expenses. The principal items of cost in general are interest expense, taxes, wages, and fuel and material costs.

For this purpose, Table 2 was prepared to show these and other expenses and information, as follows:

1. Interest on investment in road and equipment.
2. Interest accrued on funded debt.
3. Tax accruals.
4. Total employee compensation.
5. Fuel and other material and supplies.
6. Total operating expenses.
7. Operating revenues.
8. Net railway operating income.

This table is lacking in considerable early data, and for this reason its value is somewhat limited.

It may be noted from this table that in 1890, tax accruals were only 3 percent as great as operating revenues, and 9 percent as great as net railway operating income. In 1943 they had risen, until they were 20 percent as great as operating revenues and 136 percent as great as net railway operating income. The comparative percentage decreased in 1945 to 4 percent of operating revenues and 97 percent of net railway operating income. This indicates that government often receives better treatment from operations than the investor. The investment caliber of railroad securities, which is a measure of their ability to attract capital to provide more efficient facilities, is reduced by the adverse affect of high taxes on net railway operating income.

Column 2 of Table 2 shows interest on investment in road and equipment figured at a rate of 5 percent. Column 9 shows net railway operating income. Comparison of columns 2 and 9 reveals only 13 instances from 1890 to 1945 in which net operating income has equalled or exceeded 5 percent on investment. In many cases it has been far less, while in 1920 it was practically nothing.

Net income figures, which are not included in this table, showed a maximum return of only 3.8 percent, while in some years deficits were shown. This is another instance wherein the earnings records are such as to discourage the investor in railroad securities.

In analyzing interest accrued on funded debt, in column 4, it is noted that from 1876 until 1931 this item of cost increased at practically the same rate as investment in road and equipment, but whereas the latter has shown a slight increase of 3 percent from 1931 to 1945, interest expense has decreased 28 percent. This was effected largely by retirement of debt or by refunding at lower interest rates in the last few years.

Railroad expenses and net revenue have a mutual effect on each other. Expenses detract from net revenue, which indirectly affects cost. A railroad with good earning power has the money or the credit to attract investment money, which can be used in reducing costs or handling increased business.

Through prudent expenditures, more economic operation may be brought about. Higher sustained and average speeds, heavier train loads, heavier loadings per car, longer tie and rail life, lower maintenance of way and equipment, and lower operating costs in general, and a strong competitive position with other transportation agencies, etc., can be brought about by investment in or expenditures for necessary additional facilities or improved operating conditions. Such expenditures may be made for reducing grades and curves, strengthening bridges, increasing weight of rail sections and size of tie plates; treating ties and timber, purchase of ballast cleaning machinery, and improving roadbed and drainage; for automatc signaling, remote control and CTC installations; for modern communication facilities, including radio on trains; for teletype, tele-

TABLE 2

Railroad Statistics

Operating and Other Expenses and Results

1871-1945 (f)

1	2	3	4	5	6	7	8	9
Year	Interest @ 5% on Investment in Road and Equipment ($000's)	Tax Accruals ($000's)	Interest Accrued on Funded Debt ($000's)	Total Employee Compensation ($000's)	Fuel and Other Material and Supplies ($000's)	Total Operating Expenses ($000's)	Operating Revenues ($000's)	Net Railway Operating Income ($000's)
[e]1871	104,896					261,583	403,329	
2	143,559					299,487	465,241	
3	172,952					342,609	526,420	
4	186,449					330,895	520,466	
5	205,282					317,560	503,066	
6	204,333		[b]93,560			310,805	497,258	
7	209,010		98,821			301,932	472,909	
8	208,317		103,161			302,528	490,103	
9	220,826		112,238			309,076	525,621	
1880	232,680		107,866			358,176	613,734	
1	278,900		128,587			429,374	701,781	
2	301,755		154,295			489,893	770,210	
3	334,238		173,139			525,406	823,773	
4	346,228		178,058			506,505	777,396	
5	351,881		187,426			503,075	772,569	
6	362,750		189,036			529,337	829,941	
7	389,974		203,790			605,162	940,151	
8	417,215		207,124			658,625	960,257	
9	429,904		218,974			680,803	1,002,926	
[f]1890	[b]406,683	29,806	221,500			692,094	1,051,878	329,978
1	[b]422,243	32,052	219,521			731,888	1,096,761	332,822
2	[b]434,504	32,751	240,075			780,998	1,171,407	357,658
3	446,877	35,071	250,177			827,921	1,220,752	357,760
4	453,674	36,556	252,780			731,414	1,073,362	305,391
5	460,175	38,146	252,513			725,720	1,075,371	311,505
6	475,016	37,962	249,624			772,989	1,150,169	339,219
7	485,466	41,119	247,880			752,525	1,122,090	328,446
8	488,029	41,929	246,127			817,973	1,247,326	387,424
9	498,092	44,397	251,158			856,969	1,313,610	412,244
1900	513,166	44,445	252,950	577,265		961,429	1,487,045	481,171
1	520,255	46,708	262,095	610,714		1,030,397	1,588,526	511,421
2	532,916	50,054	274,422	676,029		1,116,249	1,726,380	560,077
3	548,675	53,252	283,953	757,321		1,257,539	1,900,847	590,056
4	575,577	56,802	297,675	817,599		1,338,896	1,975,174	579,476
5	597,567	58,712	310,632	839,945		1,390,602	2,082,482	633,168
6	621,014	69,064	322,556	900,802		1,536,877	2,325,765	719,824
7	651,517	73,743	344,243	1,072,386		1,748,516	2,589,106	766,846
8	660,688	78,674	368,296	1,035,438		1,710,402	2,440,639	634,794
9	680,459	85,140	382,675	988,324		1,650,034	2,473,205	710,474
1910	727,891	98,035	399,582	1,143,725		1,881,879	2,812,142	805,097
11	780,619	102,657	410,327	1,208,466		1,976,332	2,852,855	744,669

TABLE 2 (Continued)

1	2	3	4	5	6	7	8	9
Year	Interest = 5% on Investment in Road and Equipment (000's)	Tax Accruals (000's)	Interest Accrued on Funded Debt (000's)	Total Employee Compensation (000's)	Fuel and Other Material and Supplies (000's)	Total Operating Expenses (000's)	Operating Revenues (000's)	Net Railway Operating Income (000's)
1912	800,237	113,819	429,027	1,252,348		2,035,058	2,906,416	727,458
3	829,430	[c]122,005	[d]434,753	1,373,831		[c]2,235,923	[c]3,193,118	[c]805,266
4	857,689	140,470	442,595	1,381,117		2,280,416	3,127,730	674,190
5	872,071	137,775	464,186	1,277,663		2,088,683	2,956,193	694,276
6	884,471	150,015	474,535	1,506,961		2,277,202	3,472,642	1,002,935
7	928,716	218,632	474,123	1,762,965		2,906,283	4,115,413	950,557
8	949,238	229,533	468,286	2,665,013		4,071,522	4,985,290	646,223
9	965,006	239,123	476,075	2,897,769		4,498,817	5,250,420	454,132
1920	992,466	289,272	500,354	3,754,281		5,954,394	6,310,151	12,101
1[j]	1,016,461	283,163	529,398	2,823,920		4,668,998	5,632,665	601,139
2	1,029,000	308,145	538,594	2,693,292		4,509,991	5,674,483	769,411
3	1,068,643	339,577	551,705	3,062,026	1,738,703	4,999,383	6,419,210	974,918
4	1,109,113	347,437	588,301	2,882,658	1,343,055	4,608,807	6,045,252	984,463
5	1,160,860	365,790	583,875	2,916,193	1,392,043	4,633,497	6,246,884	1,136,728
6	1,194,037	396,538	581,709	3,001,804	1,559,032	4,766,235	6,508,679	1,229,026
7	1,222,694	383,112	583,452	2,963,034	1,395,928	4,622,521	6,245,716	1,077,842
8	1,243,799	395,631	578,831	2,874,429	1,271,341	4,508,606	6,212,464	1,182,467
9	1,273,252	402,698	580,770	2,940,206	1,329,535	4,579,162	6,373,004	1,262,636
1930	1,302,550	353,881	588,742	2,588,598	1,038,500	3,993,621	5,356,484	874,154
1	1,304,745	308,492	592,866	2,124,784	695,000	3,273,906	4,246,385	528,204
2	1,304,350	279,263	591,340	1,535,066	445,000	2,441,814	3,168,537	325,332
3	1,295,098	253,522	590,230	1,424,392	465,850	2,285,212	3,138,186	477,326
4	1,284,080	243,646	569,760	1,541,313,	600,224	2,479,997	3,316,861	465,896
5	1,275,023	240,760	559,187	1,666,229	593,025	2,630,177	3,499,126	505,415
6	1,271,619	324,858	548,452	1,873,819	803,421	2,973,366	4,108,658	675,600
7	1,281,804	331,013	532,237	2,013,677	966,383	3,165,154	4,226,325	597,841
8	1,279,787	346,236	521,758	1,771,083	583,282	2,762,681	3,616,072	376,865
9	1,276,908	361,617	512,283	1,889,130	769,314	2,959,438	4,050,047	595,961
1940	1,282,301	402,953	547,333	1,990,631	854,463	3,131,598	4,854,712	690,554
1	1,283,449	555,970	543,954	2,360,369	1,161,274	3,709,921	5,413,972	1,009,592
2	1,291,918	1,211,775	564,174	2,966,062	1,259,811	4,653,705	7,647,886	1,499,364
3	1,307,273	1,862,940	515,617	[e]3,564,330	1,394,281	5,714,804	9,138,419	1,370,568
4	1,331,583	1,861,652	488,877	[g]3,853,345		6,345,035	9,524,628	1,113,153
5	1,348,388	835,434	428,404	[g]3,859,907		7,115,391	8,986,954	858,864

Note: a = Data from 1871 thru 1889 are taken from Poor's Manual of Railroads.
b = Interest on Funded Debt from 1876 thru 1889 represents total interest paid, not merely on funded debt.
c = Classes I and II railways only.
d = Classes I and II and their lessor subsidiaries.
e = Partially estimated.
f = Data from 1890 on is taken from Statistics in the U. S. Intercorporate duplications not excluded. Except where otherwise noted, the figures cover Rys. I, II and III, subject to the general exception that beginning with 1908, the returns for switch and terminal companies have not been included, while before that year they were.
g = Class I railways only. Eastern Railroads Presidents' Conference.
h = Represents 1893 investment, less increases each year on account of change in classification in 1893.
j = Includes investment of lessor and proprietery companies.

TABLE 3

LOCOMOTIVES OF THE UNITED STATES
TRACTIVE EFFORT - 1890-1945

Year Ended	Number of Locomotives (a)	Tractive Effort	
		Total 000,000's	Average
6-30-1890	30,140		
1	32,139		
2	33,136		
3	34,788		
4	35,492		
5	35,699		
6	35,950		
7	35,986		
8	36,234		
9	36,703		
1900	37,663		
1	39,584		
2	41,225		
3	43,871	956	21,871
4	46,743	1,066	22,804
5	48,357	1,144	23,666
6	51,672	1,278	24,741
7	55,388	1,428	25,781
8	57,698	1,521	26,356
9	58,219	1,549	25,601
1910	60,019	1,637	27,282
1	62,463	1,767	28,291
2	63,463	1,844	29,049
3	65,597	1,985	30,258
4	67,012	2,078	31,006
5	66,502	2,095	31,501
6	65,314	2,115	32,380
12-31-1916	65,595	2,154	(c) 32,840
7	66,070	2,242	(c) 33,932
8	67,396	2,377	(c) 34,995
9	68,977	2,469	(c) 35,789
20	68,942	2,507	(c) 36,365
1	69,122	2,553	(c) 36,935
2	68,518	2,565	(c) 37,441
3	69,414	2,719	(c) 39,177
4	69,486	2,772	(c) 39,891
5	68,098	2,769	(c) 40,666
6	66,847	2,800	(c) 41,886
7	65,348	2,797	(c) 42,798
8	63,311	2,775	(c) 43,848
9	61,257	2,744	(c) 44,801
30	60,189	2,722	(c) 45,225
1	58,652	2,684	(c) 45,764
2	56,732	2,627	(c) 46,299
3	54,228	2,544	(c) 46,916
4	51,423	2,453	(c) 47,712
12-31-1935	49,541	2,396	(c) 48,367
6	48,009	2,351	(c) 48,972
7	47,555	2,350	(c) 49,412
8	46,544	2,318	(c) 49,803
9	45,172	2,276	(c) 50,395
40	44,333	2,257	(c) 50,905
1	44,375	2,273	(c) 51,217
2	44,671	2,314	(c) 51,811
3	45,406	2,382	(c) 52,451
4	46,305	2,446	(c) 52,822
5	46,253	2,461	(c) 53,217

Note (a) Including switching and terminal companies.

(c) Class I railways, excluding switching and terminal companies.

phone, labor-saving and off-track equipment; for other maintenance of way, equipment and other departments' needs; improved yard arrangement, hump operation with retarder control, efficiently designed roundhouses, engine terminals, repair tracks and shops; for more powerful and efficient locomotives, and for cars of greater capacity; for efficiently arranged freight and passenger terminals and equqipment, and many other things too numerous to mention.

As an illustration, statistics in Table 3 show the total number of locomotives and their total and average tractive power. It is interesting to note that the number of locomotives, after reaching a high of 69,486 in 1924, decreased to 46,253 in 1945, or 33 percent. At the same time, while there was a decrease of 12 percent in total tractive power, average tractive power per locomotive increased 33 percent. In view of the fact that revenue ton-miles increased 75 percent during this period, the general benefits from the purchase of more powerful locomotives is quite evident. Illustrations of a similar nature as to larger cars, treated ties, etc., are quite numerous and show the effect of capital expenditures on costs.

The personnel problem of recent years has had more pronounced effect on costs than ever before. The past effect of this is continuing and is not likely to diminish except through labor-saving economies. Some of the principal factors entering into the personnel problem are such things as, the eight-hour law, full-crew laws, wages and punitive time, so-called feather-bed rules, retirement and pension laws, vacations, hospitalization, sick benefits, and many others. Wages are becoming increasingly important in transportation costs.

In 1900 the average compensation per employee was $567, while in 1943 it had increased to $2,591 approximately, or more than 350 percent. Wholesale prices during this same period increased 84 percent. Operating expenses had increased only 13 percent in terms of the current dollar, indicating that many economies and improvements had been instituted to offset increased wage costs.

Net operating income during this same period was $2.54 per 1000 traffic units in 1900 and only $1.79 in 1941, a decrease of 30 percent. However, when stated in terms of the constant dollar of 1926 purchasing power, these figures become $5.77 in 1900 and $2.15 in 1941, a decrease of 63 percent.

There have been rapid upward changes in costs of labor and material since 1941 which at this time can not be measured, as the traffic volume during the war period was so high that the effect of higher wage costs might be temporarily overcome, while the effect on net operating income per 1000 traffic units is difficult to predict.

The cost of fuel and other material and supplies is another vital element of cost, representing 35 percent of operating expenses in 1923, 18 percent in 1932, and 24 percent in 1943. The importance of proper control of these expenses and of effecting all economies possible is easily realized.

Examination of Tables 4 and 5 shows the growth of the railway system of the United States and the mutual relationship between the growth and prosperity of the country and the railroads in general.

These tables show that the population increased from 63.1 million in 1890 to 140.4 million in 1945, or 123 percent. During the same period the miles of railroad owned increased 39 percent, while traffic units increased from 111.8 billion to 959.6 billion, or 759 percent. The fact that population increased three times as fast as railroad mileage, while traffic units increased six times as fast as population, seems to indicate that the greatest increases in population were in territories served by railroads, and that business or commercial development was greatly dependent on railroad expansion and development. That the general prosperity grew rapidly during this period is shown by the fact

TABLE 4

TRENDS IN POPULATION, RAILROAD MILEAGE, WHOLESALE PRICES AND NATIONAL INCOME
Continental United States, 1840-1945

Year	Population of continental United States	Miles of road owned	Index of wholesale prices (1926=100.0)	Realized national income: Current dollars (000,000)	Realized national income: Constant dollars of 1926 purchasing power (000,000)
1840	17,069,453	2,818	71.1	a$1,631	a$3,295
1841	"	3,535	70.5	"	"
1842	"	4,026	65.7	"	"
1843	"	4,185	61.8	"	"
1844	"	4,377	62.1	"	"
1845	"	4,633	62.6	"	"
1846	"	4,930	64.8	"	"
1847	"	5,598	64.9	"	"
1848	"	5,996	61.8	"	"
1849	"	7,365	60.1	2,420	5,319
1850	23,260,638	9,021	62.3	"	"
1851	24,085,782	10,982	64.5	"	"
1852	24,910,926	12,908	62.5	"	"
1853	25,736,070	15,360	66.4	"	"
1854	26,561,214	16,720	68.8	"	"
1855	27,386,359	18,374	68.9	"	"
1856	28,211,504	22,016	68.9	"	"
1857	29,036,649	24,503	68.5	"	"
1858	29,861,794	26,968	62.0	"	"
1859	30,686,939	28,789	61.0	4,311	9,095
1860	31,502,613	30,626	60.9	"	"
1861	32,214,118	31,286	61.3	"	"
1862	32,925,623	32,120	71.7	"	"
1863	33,637,128	33,170	90.5	"	"
1864	34,348,633	33,908	116.0	"	"
1865	35,060,138	35,085	132.0	"	"
1866	35,771,643	36,801	116.3	"	"
1867	36,483,148	39,250	104.9	"	"
1868	37,194,653	42,229	97.7	"	"
1869	37,906,158	46,844	93.5	6,827	8,995
1870	38,655,016	52,922	86.7	"	"
1871	39,814,757	60,293	82.8	"	"
1872	40,974,498	66,171	84.5	"	"
1873	42,134,239	70,268	83.7	"	"
1874	43,293,980	72,385	81.0	"	"
1875	44,453,721	74,096	77.7	"	"
1876	45,613,462	76,808	72.0	"	"
1877	46,773,203	79,088	67.5	"	"
1878	47,932,945	81,767	61.7	"	"
1879	49,092,687	86,584	58.8	7,227	15,183
1880	50,262,382	93,296	65.1	"	"
1881	51,541,575	103,143	64.4	"	"
1882	52,820,768	114,712	66.1	"	"
1883	54,099,961	121,455	64.6	"	"
1884	55,379,154	125,379	60.5	"	"
1885	56,658,347	128,361	56.6	"	"
1886	57,937,540	136,379	56.0	"	"
1887	59,216,733	149,257	56.4	"	"
1888	60,495,927	156,173	57.4	"	"
1889	61,775,121	161,319	57.4	10,701	23,675
1890	63,056,438	163,597	56.2	"	"
1891	64,361,124	168,403	55.8	"	"
1892	65,665,810	171,564	52.2	"	"
1893	66,970,496	176,461	53.4	"	"
1894	68,275,182	178,709	47.9	"	"
1895	69,579,868	180,657	48.8	"	"
1896	70,884,554	182,777	46.5	"	"
1897	72,189,240	184,428	46.6	"	"
1898	73,493,926	186,396	48.5	"	"

TABLE 4 (Continued)

Year	Population of continental United States	Miles of road owned	Index of wholesale prices (1926=100.0)	Realized national income: Current dollars (000,000)	Realized national income: Constant dollars of 1926 purchasing power (000,000)
1899	74,798,612	189,295	52.2	15,364	36,066
1900	76,129,408	193,346	56.1	16,158	36,557
1901	77,747,402	197,237	55.3	17,170	37,903
1902	79,365,396	202,472	58.9	18,444	39,750
1903	80,983,390	207,977	59.6	19,595	40,319
1904	82,601,384	213,904	59.7	20,090	41,767
1905	84,219,378	218,101	60.1	21,428	44,549
1906	85,837,372	224,363	61.8	23,165	46,610
1907	87,455,366	229,951	65.2	24,403	46,482
1908	89,073,360	233,468	62.9	23,458	46,636
1909	90,691,354	236,834	67.6	28,700	58,100
1910	92,267,080	240,293	70.4	30,400	58,300
1911	93,682,189	243,979	64.9	30,500	56,600
1912	95,097,298	246,777	69.1	32,900	60,600
1913	96,512,407	249,777	69.8	34,800	62,300
1914	97,927,516	252,105	68.1	33,900	59,700
1915	99,342,625	253,789	69.5	37,000	64,500
1916	100,757,735	254,037	85.5	44,800	72,700
1917	102,172,845	253,626	117.5	53,700	74,100
1918	103,587,955	253,529	131.3	58,300	68,600
1919	105,003,065	253,152	138.6	68,200	69,700
1920	106,543,031	252,845	154.4	69,500	61,300
1921	108,207,853	251,176	97.6	51,700	51,200
1922	109,872,675	250,413	96.7	59,500	62,800
1923	111,537,497	250,222	100.6	69,500	72,100
1924	113,202,319	250,156	98.1	69,100	71,500
1925	114,867,141	249,398	103.5	73,700	74,300
1926	116,531,963	249,138	100.0	76,600	76,600
1927	118,196,785	249,131	95.4	75,900	77,400
1928	119,861,607	249,309	96.7	78,700	81,100
1929	121,526,429	249,433	95.3	87,355	90,100
1930	123,091,000	249,052	86.4	75,003	77,100
1931	124,113,000	248,829	73.0	58,873	68,500
1932	124,974,000	247,595	64.8	41,690	54,000
1933	125,770,000	245,703	65.9	39,584	54,200
1934	126,626,000	243,857	74.9	48,613	64,200
1935	127,521,000	241,822	80.0	56,789	73,200
1936	128,429,000	240,104	80.0	66,941	85,400
1937	129,257,000	238,539	86.3	73,627	90,700
1938	130,215,000	236,842	78.6	67,375	84,500
1939	130,942,000	235,064	77.1	72,532	92,300
1940	131,954,144	233,760	78.6	81,347	102,600
1941	133,060,045	231,971	87.3	103,834	124,800
1942	133,770,500	229,174	98.8	136,486	148,000
1943	133,966,319	227,999	103.1	168,262	172,000
1944	132,563,271	227,335	104.0	182,260	183,500
1945	b131,975,774	226,696	105.8	182,808	179,900
1946				178,204	161,700
1947					
1948					
1949					
1950					

* Not available.
a Figure for year 1839.
b Preliminary.

Source: Population from U.S. Bureau of the Census; railroad mileage for years 1840 to 1889 from Poor's Manual of Railroads, for years 1890 to 1945 from Interstate Commerce Commission; index of wholesale prices from Bureau of Labor Statistics, U. S. Department of Labor; national income from National Industrial Conference Board.

TABLE 5

Year Ended	Miles of Road Owned per Million Population	Traffic Units per Mile of Road Owned	Traffic Units per Person
6-30-1890	2,594	683,083	1,772
1	2,617	710,240	1,858
2	2,613	747,999	1,954
3	2,635	772,269	2,035
4	2,617	689,408	1,805
5	2,596.	674,166	1,750
6	2,579	735,735	1,897
7	2,555	715,238	1,827
8	2,536	827,364	2,098
9	2,531	884,552	2,239
1900	2,540	981,198	2,492
1	2,537	1,009,638	2,561
2	2,551	1,068,588	2,726
3	2,568	1,134,590	2,914
4	2,590	1,123,362	2,909
5	2,590	1,182,313	3,062
6	2,614	1,298,696	3,395
7	2,629	1,390,544	3,656
8	2,621	1,309,088	3,431
9	2,611	1,292,597	3,376
1910	2,604	1,465,013	3,815
1	2,604	1,448,439	3,772
2	2,595	1,472,900	3,822
3	2,588	1,624,442	4,204
4	2,574	1,565,562	4,031
5	2,555	1,475,870	3,770
6	2,521	1,755,767	4,430
12-31-1917	2,482	2,094,595	5,075
8	2,442	2,123,684	5,198
9	2,411	2,005,419	4,836
20	2,373	2,198,218	5,217
1	2,321	1,682,687	3,906
2	2,279	1,795,517	4,092
3	2,243	2,122,667	4,762
4	2,210	2,002,950	4,426
5,	2,171	2,108,755	4,579
6	2,138	2,225,521	4,758
7	2,108	2,141,071	4,513
8	2,080	2,130,847	4,432
9	2,053	2,179,678	4,474
30	2,023	1,872,871	3,789
1	1,994	1,514,585	3,037
2	1,981	1,156,327	2,291
3	1,954	1,219,980	2,383
4	1,926	1,330,687	2,563
5	1,896	1,402,542	2,660
6	1,870	1,701,600	3,181
7	1,845	1,831,371	3,380
8	1,819	1,506,646	2,740
9	1,795	1,716,615	3,082
12-31-1940	1,772	1,912,165	3,386
1	1,743	2,439,076	4,252
2	1,713	3,500,543	5,997
3	1,702	4,359,261	7,419
4	1,715	4,520,085	7,752
1945	1,718	4,233,103	6,835

that realized actual national income per person increased from $212 in 1900 to $1,045 in 1943, a 393 percent increase.

Table 5 shows from 1890 to 1945:

1. Miles of road owned per million population.
2. Traffic units per mile of road owned.
3. Traffic units per person.

Examination of the figures in the second column shows that miles of road owned per million population, after irregular variations with little definite trend from 1890 to 1906, decreased steadily through the year 1943. The years 1944 and 1945 showed small increases due to the reduction in population resulting from the absence of servicemen overseas. This gradual reduction in miles of road owned per million population, amounting in all to 34 percent from 1890 to 1943, would indicate a steadily growing and more intensive use of existing railway mileage. This is borne out by the figures in column 2, where traffic units per mile of road owned show an overall increase of 520 percent. A substantial part of this increase is due to the inflated war traffic. It should be noted that traffic units per mile of road owned fluctuate considerably, and are susceptible to the influence of general prosperity, increasing in boom periods and decreasing rapidly in depression periods. Traffic units per person, shown in the last column, record a generally steady increase until 1920, with the exception of short periods from 1894 to 1897; then followed a sharp recession in 1921–22; then held at a high level through 1929; then sharply and irregularly lower through 1940, following which the influence of World War II caused a rapid rise in this item. It is evident from this that the volume of traffic that railways may expect is strongly influenced, and is greatly dependent on the general prosperity of the country; that railroad unit costs generally are relatively low or declining whenever the volume of business is heavy or increasing; also that the unit costs were relatively high or increasing whenever the volume of business was low or decreasing. The exception to this general trend was in the War and Post War I period, when a change was brought about by rising material and labor costs. The volume of traffic handled is greatly expanded during war periods and in general the unit costs point downward in the early years before prices are inflated. Density of traffic during war periods is generally a fair test of capacity and ability to handle heavy volume of traffic. Railroads have proved themselves to be indispensable during war periods as was well seen in World War I, but the enormous volume of passengers and freight, both military and civilian, that had to be carried during World War II demonstrated beyond any doubt the continued importance and necessity of railroad transportation.

This is well illustrated by a comparison of 1944 with 1918, the peak period of World War I. Revenue ton-miles in 1944 were only a little less than twice those in 1918; passenger-miles were more than twice as great; traffic units were very nearly twice as great. This traffic was handled in 1944 with about two-thirds as many locomotives and passenger cars, three-fourths as many freight cars, and with about a half million employees less than in 1918. It was handled with considerably less congestion and fewer delays, than in 1918.

This was made possible by the great improvement in equipment and facilities carried out with the more than $10 billion invested in additions and betterments; and by the improved operating methods developed, as well as by the years of cooperation which was organized and developed between the carriers, the employees and the users of transportation facilities. This fine record and the good will thus created should prove beneficial to the railroads in the coming years, and such efforts should be continued.

It is well known that federal, state, and municipal policies have a marked effect on railroad transportation and costs. The tendency to subsidize railroad competitors is adverse to railroad interests in most cases.

The amount of traffic handled by water carriers, both inland and coastal, is substantial.

The federal government has given aid to water transportation agencies to improve and extend river navigation, making harbors more generally useful the year round, and through the construction and maintenance of channels and dams. Flood control dams frequently become tax-free power development projects. The construction of dams used in the development of hydroelectric power certainly affects railroads, particularly those hauling the heavy volume of coal required for the generation of electric power. The tax-free agencies are able to supply power at lower rates than taxpaying agencies and thereby divert business from them.

The federal authorities have repeatedly proposed development in numerous streams where the areas are already adequately served by the railroads. The proposal for the Great Lakes Seaway via the St. Lawrence River would vitally affect a number of the existing transportation agencies involved in moving freight to and from the interior of the United States and Canada, and might have a restricting effect on the interior development of railways in this area. Other proposed inland waterways, such as those connecting points in Ohio with Lake Erie, would have a somewhat similar effect. There are many instances of this nature and a long analysis would be required to cover them properly.

The fulfillment of various proposals to further improve other streams would increase the amount of traffic diverted from the railways.

The Panama Canal gave great impetus to coastwise shipping, by shortening the water route between the East and the West. The development of the Florida Ship Canal would tend to increase the development of coastal shipping along the Atlantic Seaboard and in the Gulf area. The development of the Erie Canal had a marked effect on rates for certain commodities moving from the midwest to the Atlantic Seaboard.

Highway transportation is growing and has become an important competitor of railroads. This will continue to adversely affect the railroads as long as the users are not required to pay commensurate costs.

Municipal governments have provided subsidies for the acquisition and construction of air fields and airports at many points. New York City offers an excellent example of this form of aid.

Other acts or restrictions of government agencies affecting railroad costs that may be mentioned are: The Act to Regulate Commerce 1887, under which the Interstate Commerce Commission was created; consolidation laws and the Washington Agreement; reorganization laws, land grants, bankruptcy, control of rates and fares, recapture clause, Transportation Act of 1920, restrictions on train length, ODT, the control of abandonments and retirements, government operation and control, and so on.

In the end all this means loss of traffic by railroads to agencies which neither support themselves nor pay the taxes normally required of privately operated utilities. The tax base is thus constantly being reduced, while the overburden continues to grow. The examples of such policy or tendency are almost innumerable, and spread from border to border, and from coast to coast. If left unbridled, such growing tendencies by government could result in the breakdown or complete subsidy of all transportation agencies, including railroads.

Another vital factor in railroad costs of operation is the character of the territory traversed. Grades and curves influence train loads and the number of trains, as well as

the cost of fuel, wear and tear on equipment, rail, ties, etc. They affect speed, which in turn influences the engine and car-miles per day, and thereby the number of locomotives and cars required to handle the traffic. This is just another way of saying that railroads have large overhead expenses which can only be partially controlled, and which cannot readily be eliminated.

Railroads in general have a potential transportation capacity considerably in excess of current demand. This is one of the reasons surrounding the importance of the traffic and industrial departments, which seek to get as great a share of transportation business for the railroads as possible, and which must develop traffic by stressing to industries the benefits to be derived from locating along the railroads. This development of traffic is very important if the effect of high overhead expenses is to be diminished.

National income is also a factor influencing railroad costs provided, of course, the increase is not due to inflation. As income increases, so do the individual and group needs of the consumer, with the result that the transportation of raw materials to the mills and factories, and of the manufactured goods to the consumer, increases transportation needs, thereby increasing revenues and reducing unit costs.

Summary

The more important features brought out in the report may be stated as follows:

1. Unit operating costs are greatly influenced by and vary inversely but not directly with volume of traffic.

Unit costs, based on the 1926 purchasing power of the dollar, decreased 40 percent from 1890 to 1941, whereas traffic volume increased 406 percent. This indicates that unit costs have decreased in much smaller proportion than the increased volume of transportation would seem to warrant. This may be explained in part by the increased costs of labor and material, two factors which have greatly increased since 1941.

2. The tax burden has increased tremendously and seriously affects net railway operating income. Tax accruals were 9 percent as great in 1890; 24 times as great in 1920, when net railway operating income reached an all time low of $12,101,000, or 0.2 percent of their operating revenues; and were greater in 1943 and 1944 then net railway operating income.

3. Between 1890 and 1945 net railway operating income has equalled or exceeded 5 percent on investment in only 13 years, and net income over this period has shown a maximum return of only 3.8 percent.

4. Prudent capital expenditures are necessary to improve and develop the railroad plant to permit economic operation despite continually rising costs of wages, fuel and supplies.

5. The railroads have contributed greatly to the economic development of the country and their future is closely allied to continuing general prosperity.

6. Wars test the railroads' capacity to handle traffic and thereby indicate that their ultimate capacity is far greater than normal business volume. The indispensability of railroads in the handling of suddenly created war traffic volumes has been well proved at such times. Wars have a marked effect on railroad development and cost of operation.

7. Government subsidies to competing carriers which enables them to operate on a basis of meeting only a part of their costs are unwise economically and harmful to the railroads.

The Economic Significance

The growth of various adverse factors brought out in the early pages of this report and the steadily rising trend in the cost of railroad transportation and operation make it

incumbent on railroads in general to realize the inherent dangers that confront them unless a change is brought about. General prosperity of the nation, while necessary to railroad prosperity, has not insured it. Railroads are dependent on high business volume for their well being, but even during such periods have had considerable difficulty in getting as fair a return as the business would seem to warrant.

From this it is apparent that if the railroads are to avoid the dangers attending deficits and be assured adequate revenues, they must secure and maintain a high proportion of the transportation requirements of the country; and realize the importance of industrial development along the right-of-way and the necessity of providing at relatively low cost, service that surpasses that of competitive transportation agencies. It means also that railroads are obligated, for their own self-interest, to contribute to the general prosperity. It means that railroads must continue to effect economies in operation by modernizing facilities whenever possible. It means that the railroads of the United States must secure as high utilization of their plant as possible.

A few of the more specific ways by which the railroads may increase the volume of business, effect operating economies and thereby control or reduce expenses are by:

1. Consolidations of railroads.
2. Consolidations of terminal facilities.
3. Integrating railroad operation with the operation of other transportation agencies.
4. Retirement of lines operated at a loss due to the depletion of natural resources, where other interests are not affected.
5. Elimination of intermediate yard switching, and running more through trains.
6. Increasing average daily car, engine and train mileage, and running the maximum number of trains at the full length of which the particular road is capable.
7. Increasing the average daily ton-miles per car.
8. Increasing fuel economy.
9. Increasing operating efficiency through the modernizing and improving of facilities, and the purchase of necessary additional facilities and equipment.
10. Helping to locate and develop industries along line.
11. Providing traffic incentives or services designed to effect the use of the railroad to ultimate capacity, both for passenger and freight.
12. Encouraging of legislation to provide for equal and equitable treatment of all transportation agencies and utilities.
13. Reduction of fixed charges.

Report on Assignment 7

Coordinated Highway Service and its Effect on the Economics of Railway Operation

E. G. Allen (chairman, subcommittee), V. T. Boughton, J. L. Campbell, W. E. Chapman, S. B. Clement, C. J. Henry, H. W. Jensen, J. M. MacBride, F. H. McGuigan, Jr., R. L. Milner, F. N. Nye, H. A. Shinkle, H. D. Walker, H. P. Weidman, J. S. Worley.

This is a final report submitted as information.

Acknowledgment

Last year, on pages 167 to 187 of Bulletin 462 for November 1946 (Proceedings, Vol. 48, 1947) excerpts from the August 1945 report of H. R. Lake's AAR Subcommittee on Highway Motor Transport were, by permission of Mr. Lake and Judge R. V. Fletcher, published as part of Committee 16's report on above assignment.

Likewise, in November 1946, P. Harvey Middleton, executive vice-president of the Railway Business Association, Chicago 3, published a 75-page report entitled Transport Coordination in the United States which supplemented above named AAR report. The general headings of Mr. Middleton's report were as follows:

Chapter I. Coordination and regulation.
Chapter II. National transportation policy as defined by the ICC and U. S. Supreme Court.
Chapter III. Description of the coordinated transport service of 12 Class 1 railroads.
Chapter IV. Statements of organizations and individuals regarding coordination.

Inasmuch as Mr. Middleton's report had already covered, in a very thorough manner, the remaining phases of Committee 16's assignment on coordinated highway service, your committee, with his permission, presents herein the following descriptive matter from Chapter III of his own report and, in the nature of conclusions, excerpts on pages 59–62 of Chapter IV from an AAR statement on June 20, 1946, to the House Committee on Interstate and Foreign Commerce in regard to the National Transportation Inquiry undertaken by that Congressional Committee.

Committee 16 endorses the descriptive matter and the concluding statement quoted below from the Middleton report:

Coordinated Transport Service

The development of rail-motor operations has kept pace with the increased use of motor vehicles and the building of hard-surfaced roads. In the early days of the automotive industry our rural communities were still mired in the mud. In 1904 there were over two million miles of public roads in the United States, but not more than seven percent of that mileage had any sort of surfacing. At that time there were 54,590 private automobiles and 700 motor trucks in use in this country. The total federal expenditure for public roads amounted to $34,813 in 1904.

The rapid increase in the use of automobiles stimulated the building of good roads, and in 1916 the federal appropriations for road purposes amounted to $662,785. By that time the number of private automobiles had increased to 3,297,996, and the number of motor trucks to 215,000. It was not, however, until about that time that the motor

truck transport industry showed a definite promise of becoming an agency of intercity commercial transportation. The earlier trucks were heavy and clumsy in design and poorly sprung, with solid tires and inferior engines, very costly to operate. Trailer combinations had found only limited use. Nevertheless, with rail service under heavy pressure during the first World War, the truck of that period rendered a useful service to shippers.

In response to increasing pressure from the private car owners and the truckers, improvements in roads became a nation-wide policy, and the new highways were constructed in all directions, with the aid of funds provided by the federal, state, and local governments. The Federal Aid Road Act, which was passed in 1916, was a major factor. In 1921 the outlay by the federal government, by the 48 states, and by local rural units for highway purposes, aggregated $937,283,000. Improvements in the vehicles operating on these new roads and a great increase in their number was a natural consequence of these large public expenditures. In 1921 the number of private automobiles was 9,346,195, and the number of motor trucks, 1,117,100.

The trucking industry went through a period of uncontrolled development. The rate situation was chaotic, and there was a marked increase in the number of trucks privately owned and operated. The industry continued in a more or less disorganized state until about 1935, but a number of strong operators emerged in that period. In the meantime, many of the major railroads had organized highway subsidiaries or had made contractual arrangements for the operation of motor busses and trucks in the territories served by their lines.

In 1939 the government expenditures—federal, state, and local—for public roads totalled $2,371,317,000, and the number of private automobiles had climbed to 26,201,395, and the number of motor trucks to 4,413,692. But despite all of these vast expenditures of government funds for public roads, a large percentage of the country's road mileage remains to be surfaced. In 1943, out of a total road mileage in the United States of 2,965,000 (excluding city streets), 1,328,000 miles were surfaced. That total included a considerable mileage of "low type" surfacing. It is estimated that 70 percent of the traffic volume is concentrated on the state highway systems, 530,000 miles, of which about 22 percent is "high type" surfacing. The backbone of the intercity highway transportation is the federal-aid highway system of about 232,000 miles of the most important interstate and intercounty routes.

The privately financed railroads have contributed substantially to the building of public roads through the taxes paid by them to the federal, state, and local governments. These taxes increased from a total of $283 millions in 1921 to $1862 millions in 1944. These railroad taxes, of course, are spent not only for the building and maintenance of the public road system, but for schools and other expenses of government.

With a rail network of 228,000 miles reaching every part of the United States, the highway operations of the railways are to a large degree auxiliary or supplemental services, and are of relatively small extent, insofar as freight service is concerned. These rail-motor operations have, however, increased as the country became gridironed with roads suitable for the type of vehicles required in such operations.

The railroads employ trucks as an efficient and economical substitute for way-train service. It has been estimated that the 29 principal railroads provide rail-motor service to some 8600 stations. So far as intercity busses are concerned, the ICC in 1940 stated that of the 147 Class 1 motor carriers reporting, 14 were definitely railroad owned. The companies in which the railroads were either direct or indirect owners carried 30 percent of the revenue passengers, and had passenger revenues equalling 44 percent of all the Class 1 motor carriers of passengers.

With the advance of technology and the consequent development of new forms of transport, it becomes increasingly evident that notwithstanding the fact that the railroads will continue to carry the greater part of the total traffic load of the country, the efficient and economical performance of many traffic movements will call for the use of auxiliary service and combinations of different forms of transport to meet the varying requirements of shippers and passengers.

Coordinated services are generally carried on by one or more of four arrangements: (1) Wholly owned subsidiaries of the railroads; (2) Railway Express Agency contracts; (3) use of the existing railroad organization; and (4) contractors under rail supervision.

All of the major railroad systems have nonrail transport services of one kind or another—over-the-road movement of LCL freight, station-to-station transfers, collection and delivery by truck, bus lines, and other forms of highway operation. A recent survey of the highway operations of 25 Class 1 railroads revealed that they had rail-highway services for handling LCL freight on approximately 65,000 route miles, and the same railroads had coordinated rail-bus services amounting to 74,400 route miles.

Following are brief descriptions of coordinated transport services now in operation on a number of major lines. While services similar to those described are provided in greater or less degree by all of the Class 1 railroads, we believe that the reports included herein will serve to illustrate the kind of transport coordination which is permitted under the regulatory laws now in force and to show the rail-highway coordinated services of railroads operating in the east, the middle west and the Pacific coast territories.

Atchison Topeka & Santa Fe Railway System

The Atchison Topeka & Santa Fe Railway System, which operates 13,115 miles of railroad from Lake Michigan to the Rocky Mountains, the Gulf of Mexico and the Pacific Coast, is the parent company of two wholly-owned motor carriers, the Santa Fe Trail Transportation Company and the Santa Fe Transportation Company of California. The former conducts both bus and truck operations under certificates issued by the ICC and various state regulatory bodies. The latter company conducts intrastate bus operations in California under certificates issued by the railroad commission of that state.

The passenger operations of the Santa Fe Trail Transportation Company extend from Chicago to Los Angeles, San Diego, and San Francisco, Calif., and reach Hot Springs, Ark., Oklahoma City, Okla., and Lincoln, Neb. These operations cover approximately 12,732 route miles in the states of Illinois, Missouri, Arkansas, Oklahoma, Nebraska, Colorado, New Mexico, Utah, Arizona, Texas, and California. At the present time 312 busses are in operation over these routes.

The freight operations of the Santa Fe Trail Transportation Company cover approximately 6,700 route miles in the state of Missouri, Kansas, Oklahoma, Nebraska, Arkansas, Colorado, New Mexico, and Texas. There are some 670 pieces of freight equipment in operation. More than 2,800 persons are employed in the combined passenger and freight operations. Most of the bus and truck routes of the Trail Company either parallel the Santa Fe rail lines, serving rail stations, or lie generally in the territory served by the railway company.

Coordination of services has been established between the Santa Fe Railway Company and the Trail Company in both passenger and freight operations. Tickets sold by the Santa Fe Railway are honored by the Trail Company for bus transportation between Santa Fe rail stations in interstate commerce and in intrastate commerce in most states. In California the intrastate rail-bus coordination is conducted through the Santa Fe Transportation Company of California.

The outstanding example of rail-bus coordination on the Santa Fe is the operation between Los Angeles and San Francisco via Bakersfield. Passengers holding rail tickets between Los Angeles and San Francisco are handled by bus between Los Angeles and Bakersfield.

Rail-truck coordination is widespread over the Trail Company's system. The coordination consists of rail-truck, truck-rail, rail-truck-rail, and truck-rail-truck service, under which the Trail Company handles LCL freight for the railroad under the railroad's bills and tariffs, and the railroad handles freight originated by the Trail Company where the volume of such freight makes that operation practical. In effecting this coordination the truck and the rail facilities are consolidated wherever possible and railroad personnel, including station agents, terminal employees, etc., handle Trail Company freight and local clerical matters. Through establishment of coordinated freight service the Santa Fe Railway Company has effected a saving of 5,192 merchandise cars per month, which, when formerly operated in rail service to handle the freight now transported by truck, accumulated approximately 777,365 car-miles per month.

Two exhibits that were introduced at a recent hearing before the ICC compared the handling of rail LCL freight in March 1939, prior to the establishment of coordination, with the handling of such freight in March 1945 under the system of coordination now in effect, taking for the purposes of the comparison traffic moving from St. Joseph, Mo., and from Wichita, Kan., to 177 stations in Kansas and Missouri at which coordinated service has been established.

Prior to the establishment of rail-truck coordinated service in Kansas and Missouri, merchandise traffic originating at St. Joseph was handled by rail, and second or third day delivery was afforded at all but nearby points, such as Atchison and Leavenworth, where first day delivery was possible. In March 1939 seven merchandise cars were loaded daily at St. Joseph with freight for the 177 stations embraced in the study, with an occasional extra car. There was a total of 218 such cars for the month, containing 651,237 lb. of merchandise freight, with an average weight per car of 2988 lb. These cars accumulated a total of 29,042 car-miles during the month in handling the freight to destination.

By contrast, in March 1945 only ten rail cars were loaded with merchandise at St. Joseph. The bulk of the rail merchandise freight originating at St. Joseph was handled by truck in coordinated service, there being a total of 876,417 lb. of such freight forwarded by truck. This freight was handled by truck to final destination in some instances and in other instances was handled to a transfer or concentration point for further handling by rail. The establishment of rail-truck coordination reduced from second to first day rail merchandise service from St. Joseph to 124 of the 177 stations embraced in the study; reduced from third to first day the service to 15, from third to second day the service to 31; and resulted in no change at 7 stations. By the establishment of rail-truck coordination in the handling of rail freight from St. Joseph, the Santa Fe was able to make substantial improvement in delivery at 170 stations, and at the same time save 27,662 car-miles a month.

The exhibit showing the handling of freight from Wichita revealed that because of the more central location of Wichita, the reduction in delivery time was not so striking as in the case of St. Joseph, but the establishment of coordinated service from that point also resulted in substantial saving in merchandise cars and car-miles operated and in the reduction of delivery time to 103 stations.

Baltimore & Ohio Railroad

The first commercial railway in the United States, the Baltimore & Ohio, which was incorporated in 1827 to construct a line of railroad from Baltimore, Md., to some suitable point on the Ohio River to be determined by its board of directors, made its first run from Baltimore to Ellicott Mills, Md., a distance of 13 miles, on August 28, 1830, with the "Tom Thumb," an engine about the size of a handcar. From that early line has grown a railroad system of 6200 miles with a network of lines extending from the eastern seaboard to the middle west.

The non-rail transport services of the B. & O. include the following:

The West Virginia Transportation Company was organized in 1927, and is engaged in passenger transportation by bus. In 1945, in operations covering 724 miles of exclusive West Virginia highway, this company handled 1,664,680 passengers and had a gross revenue of $923,593.

Before the turn of the century the Baltimore & Ohio Railroad was operating what is known as the Blue Line Transfer in the City of Baltimore. That trucking operation is still being carried on, and consists largely of a pick-up and delivery service for certain freight forwarders, the trucking of freight for firms which lease space in Camden Warehouses, a Baltimore & Ohio Railroad subsidiary, and trucking for various departments of the railroad.

In 1937 the B. & O. inaugurated a pickup and delivery service, just as did a number of other railroads. Since that time it has furnished service to a number of communities, both large and small, for LCL shipments. In some cases shippers themselves pick up or deliver their materials and products at the railroad freight house with their own trucks, and where this is done an allowance is made. LCL shipments between freight houses and between railroads in the same terminus are handled by trucking contractors.

In common with a number of railroads, the B. & O. has adopted what is known as substitute freight service. This involves LCL freight handling between local railroad stations by motor truck instead of local freight train. The B. & O. executives are now studying the economics and the public preference for this service, on approximately 35 operations of this type.

In addition to the above rail–highway operations, the B. & O. furnished motor coach service without charge for passengers and baggage between its rail terminus at Jersey City and off-track stations and hotels in Manhattan and Brooklyn, New York.

Chicago Burlington & Quincy Railroad

The C. B. & Q. railroad system, which began serving the Middle West in 1850 with a line 12 miles long between Aurora and Turner Junction, now West Chicago, Ill., in 96 years has expanded into a modern railroad system of 9000 miles, serving 1600 communities between the Great Lakes and the Rocky Mountains. Through the controlled Colorado & Southern and subsidiaries extending southeastward from Denver, the Burlington reaches Galveston on the Gulf of Mexico.

The Burlington Transportation Company (a subsidiary of the C. B. & Q.) was organized in 1929 for the purpose of engaging in highway transportation as a common carrier. Initial motor bus operations were established over routes 800 miles in length. In the 16 years of its existence the motor bus routes have expanded into a system of 8250 highway miles, serving much of the territory served by the C. B. & Q., and extending west of the Rocky Mountain area to the Pacific Coast.

Motor truck operations, established in 1935, have developed from 2500 miles of route to 5000 miles. Total operating revenue from bus and truck operations in 1944 was approximately $10 million. While most of the Burlington Transportation Company's

bus and truck traffic moves all-highway, there is performed a substantial volume of coordinated rail-highway service which has resulted in benefit to the public through expedited—and in many cases more frequent—transportation service and through operating economies. The most practicable and effective methods of coordination developed gradually as a result of experience and study.

Administration, operation and maintenance of the highway operations are kept in the hands of men experienced in highway transportation, without interference by the railroad. The truck and bus divisions likewise are operated quite independently of one another by men experienced in those special fields.

The Burlington Transportation Company utilizes and pays for C. B. & Q. facilities and personnel where such utilization is practicable.

In 1944 the Burlington Transportation Company transported approximately 6,664,000 revenue passengers and 177,792 tons of revenue freight, producing 456,887,641 passenger-miles and 43,762,936 ton-miles. On December 31, 1944, it owned 237 motor busses and 315 trucks, tractors and semitrailers. One hundred new busses are on order.

Prior to the Office of Defense Transportation's speed reduction orders, elapsed time of the Burlington Transportation Company's through Chicago–Pacific Coast bus schedules was somewhat shorter than that of any other bus line. It pioneered the use of diesel-powered intercity bus equipment, and was one of the first highway carriers of passengers to operate air-conditioned busses. It inaugurated the operation of busses with five-position reclining seats. During the growth of the Burlington Transportation Company's bus system, it has acquired 25 other bus lines under authorization of state regulatory bodies and (since 1935) of the ICC. Without exception, these acquisitions have resulted in improved service, equipment, and facilities, and in 13 of the 25 cases the levels of fares prevailing on the lines acquired were reduced. Much stress has been and is placed upon safe operation, and the safety record of the Burlington Transportation Company over the years has been high in the industry.

On March 28, 1946, the ICC approved the sale of 51 percent of the stock of the Burlington Transportation Company (Bus Division) to the American Buslines—formerly known as All American Bus Lines.

Chicago, Milwaukee, St. Paul & Pacific Railroad

The 10,723 miles of line of the Milwaukee Road extend from Chicago to Seattle, Wash., with considerable branch mileage in the states of Wisconsin, Iowa, Minnesota, and North Dakota. The important cities served include Omaha, Minneapolis, St. Paul, Chicago, Seattle, Tacoma, and Kansas City. About 70 percent of the mileage is located in the states of Montana, South Dakota, Minnesota, Iowa and Wisconsin.

Compared to its rail operations, the use by the C. M. St. P. & P. of other forms of transportation has so far been small and restricted solely to highway bus and truck operations. In 1945, its bus mileage amounted to 146,000 miles in company operation and 216,000 miles under contract, or a total equal to about 2½ percent of its passenger train miles. Net tons carried one mile in coordinated service amounted to 562,000 ton-miles by its motor transportation subsidiary, 357,000 ton-miles by direct company truck operation, and 8,270,000 ton-miles under contract. The latter was the result of ODT Order No. 1, and some of it will in time be put back on the rails. The ton-miles handled by trucks in road service were only a fraction of 1 percent of the railroad's total ton-miles. In addition to the foregoing, 1,010,000 tons of rail freight were handled by trucks in urban pickup and delivery service.

New York Central System

The New York Central System operates about 11,200 miles of railroad in 11 states and Canada, serving the great industrial area between the Atlantic Seaboard and the Mississippi Valley. This is a highly competitive territory which is also served by numerous other railroads and Class I motor carriers. During the last 20 years the New York Central has, in connection with other improvements to its merchandise service, entered into motor coordinated transportation by means of contracts with existing motor carriers. The railroad itself does not own or operate any motor vehicles in revenue service.

It operates substituted freight service over the highways in order to improve its way freight LCL service, and to effect economies in such operations.

It has proved effective with respect to each objective, making it possible in most cases to reduce or eliminate overtime, and to improve way freight schedules. It has also materially reduced the number of box cars in local service and increased the ton-miles per day per car on those remaining. The freight handled in this service moves on railroad bills of lading and at rail rates. Joint rates are not involved.

The New York Central employs approximately 50 over-the-road substituted freight service contractors. They operate nearly 150 local routes, aggregating about 2500 route miles. These extend parallel to the railroad from nearly 100 strategically located concentration points where merchandise freight is transferred between box car and truck, and provide service to nearly 500 local way stations. This service now handles about 25,000 tons per month.

The contractor in these instances is deemed an independent motor carrier. In most cases the contractor must have interstate and intrastate cerificates as a common carrier of general merchandise over the specified routes. Many of the contractors working for the New York Central have certificates which restrict them to service which is auxiliary to or supplemental of the railroad. Only a few of the substituted freight service contractors presently engaged are Class I motor carriers.

The railroad ordinarily loads and unloads the trucks at the concentration points with a driver generally present to assist. At way stations the driver and the local agent, or a clerk, cooperate in handling the freight. The contractor is responsible to the railroad for all loss or damage to freight in his charge, and assumes liability for injury to his employees, or others, and for property damage. The railroad assumes its usual liability to the shipper.

The New York Central System at present has about one-quarter of its road mileage paralleled by such coordinated motor service.

As a result of studies in connection with the system research program a plan for extending such substituted freight service has been developed for the Big Four district. An application for motor carrier rights in the name of the New York Central Railroad is now before the Interstate Commerce Commission. This extension of service, if authorized, will involve 34 proposed truck routes, and will approximately double the scope of the New York Central's present operations. Analysis indicates such coordinated truck service will expedite handling of LCL traffic to and from way points by 24 to 48 hours, and, in some cases, even more. In addition, it will save more than enough on local train operating costs to defray the costs of engaging the necessary motor vehicles.

At over 150 terminals and interchange points throughout the New York Central System local truckers are engaged under contract to transfer interline LCL freight to other railroads. Experience indicates that it is generally quicker and frequently more economical than to perform this work by switching cars.

The New York Central has over 450 contractors performing pickup and delivery service at stations throughout the entire system. Pickup and delivery service is provided at about one-third of all system stations, although this fraction rises to about one-half after excluding nonagency stations. The number of stations at which pickup and delivery is provided does not alone reflect the true picture, because those stations where this service is not provided handled only about 3 percent of the total LCL freight. Both trucks and tractor trailers are used in these various operations. No special equipment, such as tank trucks or refrigerated trucks, are required for these operations.

The New York Central Railroad itself does not own or operate any busses. It has had, however, since 1935, a 45 percent interest in the Class B (voting) stock of Central Greyhound Lines, Inc., the remainder of which is controlled by the Greyhound Corporation.

Central Greyhound operates under its own management more than 6000 miles of route, generally paralleling the New York Central System from New York and Boston to Chicago via the main line and Michigan Central routes. Its operations also extend from Albany to Montreal, and traverse, in addition, other lesser routes within the territory. In certain cases these bus operations have proven worthwhile supplements to local passenger service.

Gulf, Mobile & Ohio Railroad

The Gulf, Mobile & Ohio Railroad operates some 2000 miles of railroad, extending from East St. Louis, Ill., to the Gulf of Mexico. Its lines operate in the states of Illinois, Kentucky, Tennessee, Alabama, Mississippi and Louisiana, and the G. M. & O. has connections with other railroads, barge lines, and switching lines at more than 50 locations. The G. M. & O. is an excellent example of a railroad which has coordinated its operations with highway transport.

Rail-highway service was inaugurated in a small way in the thirties, and since that time has grown to such an extent that today every point of the G. M. & O. is served by busses and trucks of a wholly-owned subsidiary, the Gulf Transport Company, which owns and operates 161 units of highway equipment, including 62 tractors, 13 trucks, 50 flats, 34 vans, 1 trailer, and a tank truck. An average of 182,000 truck miles are operated every month over 1811 miles of highways.

The coordinated truck–rail service provides for the loading of through package cars to distribution points, where the merchandise is transferred from cars to trucks and fanned out over the territory for a distance of approximately 100 miles. Trucks pick up freight at way points and transport it to the principal distribution points. Through merchandise cars are made at these principal distribution points from the inbound trucks, enabling the railroad to expedite the movement of its outbound merchandise.

The truck routes are arranged and scheduled so as to tie in with the railroad's trucks operated out of other distribution points. The railroad is able to obtain an orderly flow and continuity of movement of LCL traffic throughout its territory. The flexibility of this coordinated service has not only expedited the handling of its merchandise but has proved economical.

The Gulf Transport Company also operates four feeder lines. Service is rendered to inland towns handling both less carload and carload business on joint rail–motor rates. Empty trailers are placed for loading by the shipper at the inland town, and the load then is handled to the rail head and transferred to car by Gulf Transport Company. Inbound carloads are transferred by Gulf Transport from car at the rail head, and the receiver unloads the trailer at destination.

Generally, pickup and delivery service is performed for account of the railroad by contract draymen, unless the shipper or receiver elects to perform his own service under the regular tariff allowance. At some points the Gulf Transport Company performs the service for the account of the railroad, and this has enabled it to provide the public with pickup and delivery service at those places where it has been unable to arrange satisfactory contracts with local draymen.

Highway passenger service, coordinated with rail service is also operated by Gulf Transport Company with a fleet of 69 busses having a total seating capacity of 2075. Bus service averaging approximately 318,000 bus miles per month is operated over 1750 miles of highways generally paralleling the G. M. & O. and serving substantially all important railroad stations. On lines where both passenger trains and busses are operated, schedules are staggered to afford convenient and frequent services. Rail and bus tickets are interchangeable at the passenger's option between points where service is provided by both agencies. An average of over 3600 passengers per month have taken advantage of the interchangeability of tickets to secure for themselves the most convenient accommodations for their trip.

On lines where passenger train service has been discontinued and bus service substituted, the bus schedules are coordinated with passenger train schedules at interchange points, providing convenient and continuous service, including through tickets and baggage checking privileges.

In emergencies such as washouts, derailments, etc., causing interruption to railroad operations, busses are provided to relieve the situation, to enable passengers to continue their trip over the rail lines without serious delay or inconveniences.

Both busses and trucks handle considerable U. S. mail and express for the account of the railroads, relieving overloaded passenger trains or substituting entirely for passenger train mail and express service on lines where train service has been discontinued

Illinois Central System

The Illinois Central Cystem operates 6600 miles of railroad. The lines of the company extend from Chicago west through the distributing center for the wheat and cattle industries, touching the cities of Madison, Wis., Cedar Rapids, Waterloo, Council Bluffs, Fort Dodge, and Sioux City, Iowa; Omaha, Neb.; Albert Lea, Minn., and Sioux Falls, S. D. The main lines, however, extend south from Chicago to New Orleans through Springfield and Cario, Ill.; St. Louis, Mo.; Indianapolis, Ind.; Louisville, Ky.; Jackson and Memphis, Tenn.; Birmingham, Ala.; Shreveport, La.; Grenada, Brookhaven, Vicksburg, Meridan, and Aberdeen, Miss.

Early in 1939 the Illinois Central started a program to coordinate its railroad facilities with those of the highway truck in Southern Illinois for delivery of merchandise in station-to-station service. This plan has been extended from time to time to other points on the railroad, and it is hoped eventually to further extend this service to cover the entire system.

The Illinois Central has separate truck operations on its railroad, one under which it secured the certificates, and the other in which the individual truck lines hold their own certificates. Arrangements were set up with independent truck lines in accordance with provision of ODT General Order No. 1, whereby the railroad set up truck operations from 22 breakbulk points in lieu of way cars. Some of the contracts with the independent truck lines are based on per truck mile and others on a per 100-lb. basis. In addition to these contracts the Illinois Central has others with the Railway Express Agency under which trucks and drivers are leased to the railroad for operation under its own certificate, and the charges are on a per truck mile basis. There are no joint

rates on the Illinois Central, as that term is ordinarily understood, with any truck lines. All shipments are handled on Illinois Central billing and controlled entirely by the railroad, the truckers providing only the over-the-road service.

The executives of the Illinois Central feel that the method of distributing merchandise from key points in over-the-road truck service is sound. It provides better service to the small towns, reduces the number of cars in merchandise service, saves overtime in many instances to local freight trains, and enables the railroad better to meet highway truck competition.

In regard to bus operations, the Illinois Central has in effect optional honoring arrangements with motor carriers to and from some points on its line in Mississippi and Louisiana which provide that Illinois Central tickets, or those issued by other lines for routing via the Illinois Central, will be honored by the motor carriers.

Missouri Pacific Lines

The lines comprising the Missouri Pacific System total 9400 miles and serve the states of Missouri, Kansas, Nebraska, Colorado, Arkansas, Illinois, Louisiana and Oklahoma. Following is a description of the rail–highway operations with which the Missouri Pacific is directly connected.

The Missouri Pacific Transportation Company, a wholly owned subsidiary of the Missouri Pacific Railroad Company, was incorporated under the laws of the State of Delaware, November 15, 1928, as a perpetual corporation, to provide highway bus service parallel to the lines of the parent railroad.

Operations began in 1929 with a few shortlines and have gradually expanded until at present approximately 4600 route miles are operated on 26 routes in 8 states: Arkansas, Kansas, Louisiana, Missouri, Mississippi, Nebraska, Tennessee and Texas. The M.P.T. Company also owns one-third of the capital stock of Denver, Salt Lake & Pacific Stages, Inc., which in turn operates approximately 500 route miles in the states of Colorado and Utah.

For the most part the routes operated parallel those of the railroad. Coordinated service is also provided by the railroad and the transportation company through the extension of service to important towns reached by bus operation off the main railroad lines, notably, between Atchison, Kan., and St. Joseph, Mo., and between Union and Lincoln, Neb. Service is also provided between Lake Village, Ark., and Greenville, Miss., the latter point not being served by the railroad. Railroad tickets are honored on the highway bus, giving the traveling public the benefit of several additional schedules.

In many towns the railroad station also serves as the bus station, although frequently the busses make an additional station stop in the town. Where one station cares for both services, the railroad agent is also ticket agent for the M.P.T. Company and is able to offer the prospective customer the ticket and service that will best fit the passenger's need, either railroad or bus, or a combination of the two. Where an agent acts in the dual capacity of railroad–transportation company agent, joint use is made of the railroad facilities for reporting to the bus dispatcher the progress of the bus from station to station. Such facilities are also used to inform the railroad forces of bus passengers who want to catch connecting passenger trains and, of course, for general message work.

The transportation company operates three major shops (Kansas City, Little Rock, and St. Louis) and 10 garages (Kansas City, St. Louis, Poplar Bluff, Jefferson City, Mo., Memphis, Tenn., Monroe, La., Little Rock and McGehee, Ark., Houston and Brownsville, Texas). At terminals where operations do not justify operating facilities, the facilities of other bus companies are used.

There is close coordination between the railroad and the transportation company in all matters regarding schedules, stations, dispatching, training of employees, and maintenance.

The Missouri Pacific Lines' first trucking operation was established by the Missouri Pacific Railroad on March 6, 1933, between Concordia and Salina, Kans., a distance of 60 miles. This route did not parallel the line of the railroad, but was used as a connecting link for the expeditious handling of freight between points on the Kansas City–Pueblo line and points on the Atchison–Concordia, Kansas line of the Missouri Pacific. The second truck route of the Missouri Pacific Railroad was established on April 17, 1933, between Osawatomie and Durand, Kans., a distance of 102 miles. Three additional routes were established in 1933, making a total of 337 highway route miles in service at the close of that year.

In the year 1934, six additional truck routes were established, aggregating 473 highway route miles. At the close of the year 1934, the Missouri Pacific had acquired and was operating highway truck service over 810 highway route miles.

After two years of testing the practicability of coordinated highway trucking service with railroad freight train service, as a means of holding its less-carload freight traffic and in an effort to regain less-carload freight that had been lost, the Missouri Pacific Railroad concluded to further expand its coordinated trucking service, and by the close of the year 1942, it had acquired certificates of public convenience and necessity for the operation of motor trucks as a common carrier over 3889 highway route miles. It now has an application pending before the ICC covering an additional 2333 miles, all in the state of Arkansas, where no operations are now conducted.

The first truck operations in Louisiana were established by the Gulf Coast Lines on February 15, 1938, over 336 highway route miles. These operations were coordinated with the freight train service of two of the lines, the New Orleans, Texas & Mexico Railway and the New Iberia & Northern Railroad. These routes extended from Baton Rouge, La., to DeQuincy, La., including branches; from Eunice, La., to Crowley, La.; and from Port Barre, La., to Patterson, La., including branches. On September 18, 1939, trucking operations were established between New Orleans and Ft Jackson, La., a distance of 72 miles, paralleling the lines of the New Orleans & Lower Coast Railroad.

Trucking service was established in Texas on March 1, 1939. Through the purchase of the highway operating rights of the Allen Motor Transportation & Terminal, the Missouri Pacific Lines through Missouri Pacific Freight Transport Company, a Texas corporation and a wholly owned subsidiary of the Missouri Pacific Railroad Company, commenced the operation of highway trucking service in coordination with the freight train service of the Missouri Pacific Lines (Gulf Coast Lines) between Brownsville and Harlingen and between Laredo and Harlingen, a distance of 204 highway route miles. Also, on March 1, 1939, the Missouri Pacific Freight Transport Company established highway trucking operations between Waco and Mart—a distance of 20 miles—in coordination with the freight train service of the Missouri Pacific Lines (International-Great Northern Railroad). These operations were acquired through the purchase of an existing certificate from the Lester Truck Line. Additional routes covering 300 miles were acquired in Texas through purchase of existing certificates.

The highway routes acquired through purchase by the Missouri Pacific Freight Transport Company aggregated 524 miles. Additionally, 2669 route miles were acquired through application of the Missouri Pacific Freight Transport Company direct to the regulatory bodies, to bring the total to 3193 miles.

To summarize the foregoing: the Missouri Pacific Lines now operates truck service on 7082 route miles and has applications pending for 2333 route miles. All of the high-

way routes now operated except those acquired through purchase in the name of the Missouri Pacific Freight Transport Company, were acquired through direct application to the regulatory bodies having jurisdiction over such matters.

In all states except Texas, and except in Louisiana on the New Orleans & Lower Coast Railroad, truck equipment is leased and maintenance of such equipment is handled by the lessor. In Texas, all truck equipment is owned by the Missouri Pacific Freight Transport Company and maintenance of such equipment is performed by company employees in three Missouri Pacific Freight Transport Company garages, at Palestine, Houston, and Raymondville, Texas. All Missouri Pacific Lines freight stations, warehouses, and personnel are also used by highway trucking operations at points along such truck routes.

Except in Texas, all the less carload traffic moves on rail bill of lading and on railroad rates, and, in fact, are shipments of the railroad. In Texas the Missouri Pacific Freight Transport Company, in addition to substituting highway truck service for railroad service in the carriage of shipments moving under railroad billing, issues its own bills of lading and handles shipments moving in intrastate commerce in its own name under its own rates, rules, and regulations. The transport company's service is closely coordinated with the freight train service of the Missouri Pacific Lines. The substitution of rail for truck or truck for rail service is covered by tariffs on file with the ICC authorizing such substitution.

Establishment of trucking service has improved, very definitely, the less-carload service previously rendered by local trains. It has generally improved all-rail merchandise schedules by from 24 to 48 hours. In a number of instances, the improvement was as much as 72 hours, due primarily to the establishment of daily truck service, in lieu of tri-weekly local freight train service.

The railroad's plan of operation is generally as follows: Through merchandise cars are loaded on Missouri Pacific Lines at principal distributing centers, carded to break bulk at certain radial points known as "break-bulk" stations on its truck and rail routes. Such "break-bulk" stations are located strategically where main truck routes and rail operations converge or cross, or from which such rail and truck routes radiate. When the daily set-out cars arrive at the "break-bulk" stations, Missouri Pacific highway trucks are standing by for immediate transfer of freight from cars to trucks, then the trucks proceed along their scheduled routes. Outbound merchandise is handled in the reverse order, from origins near the "break-bulk" point to the "break-bulk" point for consolidation (depending upon the destination) either into a rail car or for movement to destination by truck.

New York, New Haven & Hartford Railroad

The New York, New Haven & Hartford Railroad operates 1838 miles of line in the southeastern part of the State of New York, and in Connecticut, Rhode Island, and Massachusetts. Many years ago the management of this railroad maintained that it should be permitted to enter whatever form of transportation would give the most economical and expeditious service to its patrons. It was one of the first American railroads to engage in the operation of motor busses and trucks through the organization of the New England Transportation Company in 1925 as a wholly owned subsidiary.

On August 10, 1925, motor busses were substituted for rail passenger service on branch lines where the traffic did not economically justify the continued operation of passenger train service. In addition to these "rail-saving" runs, the New England Transportation Company established routes for its own account in this railroad's territory to compete with nonrailroad operations of motor busses, and fares on these routes were maintained at competitive levels.

The New England Transportation Company now operates or participates in 27 regularly scheduled motor bus routes serving points in N.Y.N.H.&H. territory in southern New England. These operations are practically all short hauls, and mostly in sections of light traffic density. In operations of this kind, it is more efficient, more economical, and more convenient to use motor busses than passenger trains.

This railroad includes in its timetable the schedules of the New England Transportation Company's coordinated service and also the schedules of established independent local motor bus companies whose schedules are convenient for its passengers.

In July, 1929, the New England Transportation Company entered the field of motor trucking freight by performing a truck service for the transportation of less-than-carload freight for the New Haven between points in Rhode Island, in lieu of peddler cars on local freight trains. Runs of this nature are termed "rail-saving" runs. Within two years of its inauguration, this type of service expanded to cover the whole territory of the railroad. This subsidiary now operates 96 so-called "rail-saving" routes for the account of the railroad. The equipment operated by the New England Transportation Company consists of straight trucks and tractor-semitrailer units for the handling of general merchandise only, and none of the equipment is refrigerated.

The railroad service of LCL traffic has been improved greatly by the use of these "rail-saving" truck runs. These truck routes are based on railroad freight concentration stations where straight cars of LCL freight originate and terminate, thereby eliminating LCL freight from local way freight service and improving the over-all service. Terminal switching has been reduced by the handling of freight in motor trucks in lieu of ferry cars. All railroad freight moved by these "rail-saving" runs moves under railroad freight tariffs. This faster service has resulted in the recovery of some traffic lost to competing carriers. Substantial savings are made by the railroad as a result of this service.

The New England Transportation Company performs a freight common carrier service for its own account throughout the territory served by the railroad. This service was established to compete directly with the independent non-railroad motor truck operations in this territory. This service was established prior to the advent of motor truck regulations. The New England Transportation Company has 48 truck routes in this service.

This subsidiary also performs the pickup and delivery service for the railroad on less-than-carload freight at 28 of the 107 stations on the New Haven at which this service is rendered. This railroad does not employ the New England Transportation Company exclusively for the handling of rail pickup and delivery service; it also employs the Railway Express Agency and a large number of independent local truck operators.

The New England Transportation Company also handles pool car traffic moving in carload lots by rail for local distribution throughout the territory served by the railroad.

Another operation employed by the New Haven which has to do with coordination of transport in the public interest is the utilization of the flat cars for the transportation of highway truck trailers over the rails. This railroad operates 50 flat cars in shuttle service for the handling of trailers of several trucking companies, including the New England Transportation Company. This rail operation is from Boston, Mass. and Providence, R. I., to Harlem River, N. Y. (New York City), rail distances of 207 and 180 miles, respectively. Flat cars are loaded with trailers at one point at night and unloaded at destination the next morning, and reloaded the same night and returned the following morning. This operation was inaugurated in 1937.

The business the railroad has realized from this "trailer-on-flat-car" operation is traffic which certainly would not move by rail if the service had not been established.

In brief, the arrangement coordinates railroad and highway operations in a mutually beneficial manner.

Pennsylvania Railroad System

The Pennsylvania Railroad operates over 11,500 miles of line from the eastern seaboard through the middle west to Chicago and St. Louis. Including the District of Columbia, its operations extend into 13 states.

In the early twenties, in order to improve service and reduce the number of "peddler" freight trains (because of their interference with through traffic), the Pennsylvania Railroad inaugurated substituted service for the handling of LCL traffic. Merchandise freight to and from outlying stations was moved through zone concentration points by motor truck, giving all stations within the zone the same service as the zone or central stations. In addition to economies resulting from this change in the method of handling the freight movement was expedited and the all-round performance materially improved. At the present time there are 239 station-to-station routes in operation, covering 9008 route miles daily. During the year 1945, 560,413 tons of LCL freight were handled in substituted service.

About the same time the benefits from station-to-station operation were becoming apparent to railroad management, consideration was also being given to the movement of LCL freight by motor vehicle from one station to another within the same terminal area. Advantages similar to those secured from substituted service likewise resulted in this form of terminal transfer. The service was extended to include not only LCL freight moving from one Pennsylvania Railroad station to another in the same city, but also to interchange from a Pennsylvania Railroad station to a station of another railroad. Intraterminal service via motor truck is at present being renedered in 113 cities.

Effective December 1, 1933, the Pennsylvania inaugurated pickup and delivery service on a system-wide basis. Free service was provided in a 260-mile zone, and beyond that an additional charge was made. On May 6, 1936, the ICC approved the removal of the 260-mile limit. At present pickup and delivery service is afforded at 1232 Pennsylvania Railroad stations, which involves the use of 910 different truckers.

The Pennsylvania Railroad at present has a financial interest in 20 different trucking companies, 9 of which are wholly owned. During 1945 these companies rendered 96.2 percent of the substituted service and performed 54.3 percent of the pickup and delivery service for the Pennsylvania Railroad.

In the development of LCL traffic many stations were found to have insufficient traffic to justify the movement of a through car from the principal producing areas. To meet these situations, the Pennsylvania designed containers which are loaded five to a flat car. Origin stations load freight for specified destinations in the containers so that when the car leaves the origin station it carries containers for five different destinations. Cars move to a transfer station at Enola, Pa., near Harrisburg, where the containers are shifted by an overhead crane and when the car leaves the container transfer it contains five containers for the same destination. As the transfer of containers is done in the period alloted to the shifting of cars in the train there is no loss of time, and it means that through the use of containers smaller points for which traffic would ordinarily pass through transfers, receive the benefit of a through movement the same as if loaded in a box car.

In 1931 a new form of rail-truck operation, the demountable truck body, was inaugurated between New York, Philadelphia, Baltimore and Richmond on a limited basis. Under this arrangement truck bodies are loaded by the shipper and hauled by truck from his place of business to the rail station, where they are transferred by crane

to a rail car and moved in rail freight service to destination. The reverse operation takes place at the destination station.

As a result of the efforts to improve the transit time for LCL traffic, the Pennsylvania has maintained its position as the foremost handler of LCL traffic in the country. In the year 1945 it handled 5,061,574 tons of LCL traffic, and indications are that this figure will closely approximate 6 million tons for the year 1946.

During the middle twenties the Pennsylvania Railroad saw long-haul bus lines established paralleling its more important rail lines, with the resultant loss to passenger revenue. In 1928 it acquired a 50 percent stock interest in Pennsylvania Greyhound Lines, Inc., and, through coordination, was able to eliminate many unprofitable passenger train miles. At the present time there are 18 routes operated by bus lines on which rail tickets are honored, mostly in branch line territory where all passenger train service has been eliminated.

Seaboard Air Line Railway

The Seaboard Air Line Railway operates 4170 miles of line in Virginia, Maryland, Georgia, Alabama, Florida and the Carolinas, with connecting lines to Washington, Baltimore, Philadelphia, and New York.

Some 13 years ago the Seaboard Air Line Railway began a program of supplementing its rail service with trucks, and this coordinated service has been progressively expanded until it now comprises approximately 1500 miles of highway service, as represented by 12 separate operations. The primary objective is to provide a more flexible means of handling less-carload freight shipments, and to a lesser extent mail and express, to the smaller stations served by Seaboard rails, and the auxiliary utilization of trucks has resulted in a number of improvements that are very beneficial both to the Seaboard and its patrons. Among these are the following:

Delivery of less-carload freight is expedited.
Overall train schedules are speeded up.
Delivery of carload business is advanced.
Average number of freight cars utilized is reduced.

In addition to these advantages from a service standpoint, the distribution of LCL freight to way stations can be more economically performed through the coordinated employment of highway units.

Southern Pacific Company

The 12,600 miles of railroad of the Southern Pacific System extend west from Ogden, Utah, to San Francisco, Calif., and southeasterly to Yuma, Ariz. through the states of Arizona, New Mexico, and Texas to New Orleans, La.

The major coordinated service of the Southern Pacific has been in the trucking field. For the past 15 years, the Southern Pacific has been progressively using motor vehicles, auxiliary and supplementary to its rails, and thus has provided a complete and efficient service for the public. In coordination with its rail service, the Southern Pacific (through its wholly-owned trucking subsidiary, the Pacific Motor Trucking Company) operates as a common carrier over some 10,000 miles of highway, employing about 1000 units of trucking equipment in such service. It also uses its trucking service to reach into territory not served by rail for the purpose of feeding traffic to the rail lines. In addition to employing several hundred units of trucking equipment under contract for the purpose of performing terminal service, it maintains equipment in 78 cities and towns on its rails where satisfactory terminal service cannot be obtained under contract.

Concluding Statement

On June 20, 1946, the AAR submitted a statement to the House Committee on Interstate and Foreign Commerce, in response to a communication from Chairman Clarence S. Lea, in regard to the National Transportation Inquiry undertaken by that committee. The following is a digest of that part of the statement of the AAR dealing with the furtherance of coordination, and federal aid to transportation:

> The starting point of any broad consideration of transportation is the fact, demonstrated and highlighted by the emergency of war, but just as true in peace, that railroads are, and for the foreseeable future will continue to be, the basic and essential transportation agency in the United States.
>
> This does not mean that the railroads are entitled to, or should have, special or preferential treatment. The inherent efficiency of the rail method of moving persons and property in trains of cars on tracks is so great that no such treatment is necessary. It does mean, however, that in doing their essential work the railroads should not be handicapped by unnecessary or artificial restrictions, and that their strength should not be sapped and their usefulness impaired by special preferential treatment for other carriers.
>
> The several hundred separately operated railroads in the United States have widely varying physical and operating conditions, traffic volume and earning power, but they have so successfully coordinated their services to the public that it is a commonplace of commerce on this continent that a freight car may move from any station on one railroad to any station on any other railroad on through schedules and through rates. So smoothly does this essential coordinated service work, day after day, that the several hundred railroad companies have come to be thought of by the public, and to be treated by the press, and by law and regulating bodies, as one great system. There is indeed in all the world no such coordinated national system of transportation as is conducted in the United States by its several hundred railroads . . .
>
> Under our system of regulation of transport, anyone wishing to enter any field of commercial carrier service must first make a proper showing of public interest, upon which the appropriate regulatory body can find that the public welfare and convenience would thereby be served. Beyond this there should be no restriction upon any form of transportation making use of other means of transport; and there should be no arbitrary general prohibition of such use. The controlling consideration should be the public service and public interest, and not the selfish interest of any form of transport . . .
>
> In our opinion, the most flagrant departure by the government from its Declaration of Policy with respect to transportation has been its practice of promoting the activities of particular carriers at the expense and to the disadvantage of others. It would be difficult to think of a surer way to defeat the declared purpose to foster and preserve the inherent advantages of each mode of transportation than for the government to single out particular types for special promotion through subsidies in one form or another, however disguised, thus giving them a wholly artificial advantage over other types not so favored.
>
> As a general rule at least, the only form of promotion of carrier activities in which the government should engage, because it is the only form of promotion that will prove in the long run to be in the real public interest, is that indirect but nevertheless effective promotion of all economically justifiable carrier activities

which will come about as the result of fair and impartial treatment by the government of all forms of transportation in all respects. If any exception at all to that rule is warranted, it is only in the case of some new form of transportation during the pioneer period of its development. In our opinion, all presently existing modes of transportation are well past that stage, so there is no justification for direct government promotion of the activities of any of them . . .

Included in the steps which the AAR suggests to make effective the declared national transportation policy and bring about further coordination in transportation facilities and services are: (a) The removal of doubt as to the legality under antitrust laws of joint activities; (b) opening of the way for a single interest to engage in two or more types of transportation on equal terms with agencies engaged separately therein; and (c) the regulation of all modes of transportation by a single agency.

The AAR favors a continuance of the present policy of making consolidations permissive rather than mandatory, while at the same time encouraging them by removing them from the prohibitions of federal and state antitrust laws when found by the regulatory body to be in furtherance of the public interest. As to consolidations of different types, the AAR makes the following statement:

As to consolidations of carriers of different types, we think there is need for a change both in legislative and administrative policy. We think there should be no more restrictions against such consolidations than apply to consolidations between carriers of the same type. The principle involved is the same in either case and the same rule should govern.

There has been a tendency on the part of many persons to consider railroads, water carriers, motor carriers, pipe lines and air carriers, as being entirely separate and distinct industries instead of being, as they are, merely alternate means of providing transportation for persons or property. The basis for this view is partly historical and partly the supposed interests of the respective agencies of transportation. Representatives of other agencies express the fear that if left free to do so the railroads, because of their greater size and more extensive financial resources, would ultimately dominate the entire transportation field. Such considerations, however, overlook the broad public interest in the matter, which alone should be controlling. The question involved is entirely an economic one and should be dealt with as such . . .

A transportation agency utilizing various modes of transportation in its operations would in its own self-interest perform each operation by the mode best adapted for its performance. It would have no motive to reach after and take from other modes the traffic for which they are better fitted than it, thereby increasing the total cost of moving the nation's traffic.

It is clearly in the public interest that operation of multiple-type transportation agencies be permitted, as the same degree of efficiency and economy of service cannot be achieved through arrangements for joint service by separate competing interests . . .

Many railroads own subsidiaries which operate as common carriers by motor vehicle. In some instances, however, restrictions have been placed upon such operations by the ICC which prevent their utilization to the best advantage and which find no counterpart in the operations of independent motor carriers. Some of the railroads also own or control water carriers, although the laws now in effect, particularly the Panama Canal Act, have greatly limited the opportunities for

doing this, contrary, as we believe, to the public interest. Other railroads wish to operate common carrier air service, but are practically prohibited from doing so by the administrative policy adopted by the Civil Aeronautics Board, based in part at least on what we consider to be a misinterpretation of the statute. All such artificial restrictions against the operation of multiple-type transportation agencies should be removed. In urging their removal, the railroads seek no special favors. They simply urge that there should be no discrimination against them or any other type of carrier in this regard. All should be treated alike in this as in all other respects if the public is to receive the best possible service at the lowest cost.

Report of Committee 13—Water Service and Sanitation

H. F. King, *Chairman,*
R. C. Bardwell
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I. C. Brown
R. W. Chorley
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J. W. Ussher
C. P. Van Gundy
H. W. Van Hovenberg
R. E. Wachter
E. L. E. Zahm
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, including recommended revisions ..... page 64

2. Intercrystalline and other types of corrosion of steam boilers.
   Progress report, presented as information ..... page 66

3. Federal and state regulations pertaining to railway sanitation, collaborating with Joint Committee on Railway Sanitation, AAR.
   Progress report, presented as information ..... page 67

4. Mechanics of foaming and carry-over in locomotive boilers.
   No report.

5. Current developments in sanitation practices as applied to camp cars and bunk houses.
   Progress report, presented as information ..... page 68

6. Silica scale prevention.
   Progress report, presented as information ..... page 74

7. Requisites of water and wetting agents used in washing passenger train cars.
   Final report, offered as information ..... page 78

8. New developments in water conditioning for diesel locomotive cooling systems and steam generators.
   Progress report, presented as information ..... page 80

The Committee on Water Service and Sanitation,
H. W. King, *Chairman.*

AREA Bulletin 469, November 1947.

Homer H. Richardson

Homer H. Richardson, who had been a member of the Association since 1923, died July 5, 1947. He was born in Savonburg, Kans., July 23, 1898. His higher education was obtained at Kansas University. From 1918 to 1922 he was employed as chemist on the Missouri Pacific Railroad. For a short time he was assistant water service engineer on the St. Louis Southwestern Railway, but returned to the Missouri Pacific as engineer water service in 1923, serving in that capacity until 1928 when he became associated with the National Aluminate Corporation as assistant vice-president. He occupied this position at the time of his death.

He is survived by his wife, Helen Jackson Richardson, two sons, Robert and Paul, and one daughter, Carol.

Mr. Richardson was a member of the Water Service committee from 1924 to 1929, during which time he made many valuable contributions.

It was a privilege to have been associated with him and to have known him as a friend.

Report on Assignment 1

Revision of Manual

H. E. Silcox (chairman, subcommittee), R. C. Bardwell, W. M. Barr, I. C. Brown, R. E. Coughlan, B. W. DeGeer, E. M. Grime, T. W. Hislop, Jr., A. W. Johnson, C. R. Knowles, W. B. Leaf, G. E. Martin, H. L. McMullin, G. F. Metzdorf, Theodore Morris, H. M. Shepard, T. A. Tennyson, J. W. Ussher, R. E. Wachter, E. L. E. Zahm.

Your committee offers the following recommendations with respect to material in Chapter 13 of the Manual:

Page 13–1

General Principles of Water Supply

B. Quality—lines 2 and 3

Delete U. S. Treasury Department and insert U. S. Public Health Service.

Page 13–19

Specifications for Laying Cast Iron Pipe

(b) Cement Joints—line 4

Delete "Dry cement" and insert "Dry portland cement conforming to AREA specifications."

Page 13–21

Specifications for Wood Water Tank

Reapprove without change.

Page 13–40

Water Treatment

Reapprove without change.

Lime-Soda Method

1. Capacity

Add the following sentence to Paragraph 2:

With the use of sludge blanket type equipment the capacity of the tank reserved for treatment may be reduced to 1.5 times the hourly capacity.

Page 13–45

Specifications for Soda Ash to be Used in Water Treatment

Reapprove without change.

Specifications for Hydrated Lime to be Used in Water Treatment

Reapprove without change.

Page 13–47

Specifications for Quick Lime to be Used in Water Treatment

Reapprove without change.

Page 13–49

Specifiations for Sulfate of Alumina to be Used in Water Treatment

Reapprove without change.

Page 13–51

Specifications for Sulfate of Iron to be Used in Water Treatment

Reapprove without change.

Page 13–65

Minimum Quantity of Scaling and Corrosive Matter Which Will Justify Complete External Treatment

Reapprove without change.

Page 13–66

Foaming and Priming

Reapprove without change.

Page 13–67

Washouts, Water Changes and Blowdown of Locomotive Boilers as Influenced by Water Conditions

Reapprove without change.

Page 13–67

Water for Drinking Purposes

Delete Paragraph 1 under the above heading and insert the following:

1. The Interstate Quarantine Regulations as prescribed under Section 361 of the Public Health Service, Act of 1944, and as published in the Federal Register under date of May 16, 1947, became effective June 16, 1947. The regulation governing interstate traffic appears as Title 42—Public Health, Chapter 1—Public Health Service, Federal Security Agency, Part 12, dated May 2, 1947, and provides that water for drinking and culinary purposes furnished by railways on passenger cars, shall be pure and from a source which is approved by the surgeon general for producing water of satisfactory sanitary quality and safety.

Pages 13–68–13–73, incl.

Water Service Records

Reapprove without change.

Page 13–77

Water Service Organization

Reapprove without change.

Report on Assignment 2

Intercrystalline and Other Types of Corrosion of Steam Boilers

R. E. Coughlan (chairman, subcommittee), R. C. Bardwell, W. M. Barr, R. W. Chorley, B. W. DeGeer, M. A. Hanson, T. W. Hislop, Jr., H. M. Hoffmeister, C. R. Knowles, Ray McBrian, Theodore Morris, S. E. Printz, R. W. Seniff, J. M. Short, R. M. Stimmel, J. E. Tiedt, J. W. Ussher, C. P. Van Gundy.

This report is submitted as information.

During the past year your committee has made an investigation of the procedure in the construction of the all-welded boiler, a number of which have now been put in service on various railroads. This is the first extensive use of the all-welded boiler in railroad service, although one such boiler had previously been used on an eastern railroad for some 10 years.

During the past year, a committee of the Master Boiler Makers' Association was assigned to a study of this type of fabrication of locomotive boilers and, with due acknowledgment to this committee, the information developed indicates that this method of welding should result in a very satisfactory boiler, free of the possibility of any seams that would facilitate concentrations of dissolved solids contributing to intercrystalline corrosion.

All parts of the shell and back end are individually laid out to insure correct alinement when assembled. The edges of shell courses are prepared for welding by machine planing the plate edge to a bevel of 50 deg. outside, 5/16 in. deep, or an included angle of 100 deg. The inside was beveled 55 deg., or an included angle of 110 deg., 5/16 in. deep. Allowance is made in the overall length for shrinkage and grinding. The ends of all shell plates are bent to the correct radius in an hydraulic press before being rolled. After the plate is rolled to the proper diameter, the longitudinal seams are prepared for submerged arc welding. By means of bolts slipped through nuts tack welded each side of the seam at the front, center and back end of the seam inside, and the bolts tightened, the plates were brought together to a maximum tolerance of 0.015 in. The edges are then tack welded together in three or four spots by hand. A starting plate, or tab, the same thickness as the shell course, is tack welded to one end of the seam. The test plate with a tab attached is tack welded to the other end of the seam. The course is then placed on rolls with the outside of the longitudinal seams at the top. The submerged arc machine is set on guide rails in alinement with the seam, the rails being tack welded or clamped to the shell. The weld is started on the tab and run continuously through the test plate. After this welding is done, the course is then rotated so that the longitudinal seam is at the bottom for the second or inside pass. The welds are ground and buffed to remove all irregularities, thus blending the welds smoothly with the plate at the weld edges. An x-ray is then made of the work and any repairs completed before the courses are released for further work.

After the longitudinal seams are welded, the courses are made round by the use of eight-leg adjustable spreaders. They are then placed on a positioner in a level position and the edges ground to a true plane, and made to correct length with shrinkage allowance. The shells are then fitted together in the vertical position and fitted to 1/64 in. tolerance. The circumferential seam is then tack welded outside. The front tube sheet is welded to the band, which was welded to the inside of the first course.

After the shell is fitted up complete, it is placed on a positioner and all seams are machine welded inside and outside. After the welds are ground and buffed, they are again x-rayed.

The back end of the boiler has the throat sheet and back head butt fitted to the roof sheet, and the sides are welded by hand. The front face of the back end is set in level position and the edge of the throat and roof sheets are ground to a true plane for correct alinement. The back end is then set against the completed shell portion for final assembly. The boiler is lined for length, height and correct alinement, after which the connection seam is tack welded before being placed on positioner for machine welding.

The fabrication of the roof and outside casing sheets then follows.

After the x-ray examination is completed, the mud ring is attached and the back head and throat sheet are fitted to the wrapper sheet, the welding of which is done manually, because of the irregular contour of the joint connecting the back and the throat to the roof and sides. After welding is completed, the welds are prepared for x-ray examination by grinding and buffing. All longitudinal and circumferential seams, as well as the wrapper sheet, back head and throat sheet seams, are examined for their full length by x-ray. After any defects are corrected, the boiler is released from final radiographic and visual inspection and it is placed on a car for stress relief. The boiler is braced to prevent warpage and thermocouples applied. The car serves as the floor of the furnace and the furnace door is lowered into a sand seal. The furnace is indirect oil fired with the combustion chamber located on the roof. The hot gasses are circulated by blowers down the side of the furnace and withdrawn from the top to be recirculated. The heat of the furnace is approximately 1100 deg. F., depending on the type of steel used in the boiler. This temperature is held for one hour per inch of thickness of the metal.

After stress relieving, the test plates are checked for tensile strength and ductility.

This committee wishes to acknowledge with thanks the valuable help and information received from the Master Boiler Makers' Association during the past year.

Report on Assignment 3

Federal and State Regulations Pertaining to Railway Sanitation, Collaborating with Joint Committee on Railway Sanitation, AAR

H. W. Van Hovenberg (chairman, subcommittee), R. C. Bardwell, R. E. Coughlan, B. W. DeGeer, R. H. George, F. L. Guy, S. H. Hailey, J. P. Hanley, K. P. Howe, A. W. Johnson, O. E. Mace, G. E. Martin, W. A. McGee, G. F. Metzdorf, L. R. Morgan, E. R. Morris, A. B. Pierce, H. E. Silcox, D. C. Teal, T. A. Tennyson, R. E. Wachter.

This is a report of progress.

The Sanitation Research Project of the AAR has practically completed the first phase of its problem of finding a solution for the handling and disposal of toilet wastes from passenger carrying railroad cars. This virtual completion of its studies on quantities of discharges, nature of discharges, and of passenger toilet use habits, will enable the project personnel to engage in the design of equipment for the handling and discharge of such wastes. Three broad methods are under study and design: (1) that of maceration, holding, and discharge under controlled conditions, with and without disinfection; (2) simple retention in a holding device for disposal at terminals; and, (3) the separation of liquid and solids contents, with discharge of the liquid and retention of the small percentage of solid matter for terminal disposal. Present emphasis is on method (1).

The new Interstate Quarantine Regulations promulgated by the Federal Security Agency, Public Health Service, became effective on June 16, 1947. These regulations embody the sanitation requirements for land and air conveyances, and were adopted following extended discussions between the federal authorities and the railroads, through the Joint Committee on Railway Sanitation. Reprints of the regulations may be secured from the Government Printing Office at 10 cents per copy.

These new regulations should be examined critically by operating, mechanical, and engineering officers of railroads, since there are new requirements of considerable importance involving submission to federal and state health authorities, where sanitation is involved, of plans for terminal, new passenger car, and dining car facilities and equipment, as well as pertinent requirements in the certification of water for drinking and culinary purposes, quality of foods furnished passengers, etc.

Members on the Joint Committee on Railway Sanitation representing the Engineering Division, AAR, are R. C. Bardwell, A. B. Pierce and H. W. Van Hovenberg.

Report on Assignment 5

Current Developments in Sanitation Practices as Applied to Camp Cars and Bunk Houses

D. C. Teal (chairman, subcommittee), R. H. George, K. P. Howe, H. L. McMullin, L. R. Morgan, A. R. Nichols, A. B. Pierce, H. M. Schudlich, H. M. Shepard, J. W. Ussher, H. W. Van Hovenberg, R. E. Wachter, E. L. E. Zahm.

This is a report of progress on a new assignment and is submitted as information. This year's report concerns only camp cars.

For a statistical background it is estimated from data furnished by AREA membership, that of the more than 300,000 maintenance of way employees of Class I railroads, approximately 30 percent, or 90,000, are required by the nature of their work to live in camp cars. More than 18,000 cars are used for the housing of these men.

It has been and still is the practice on most railroads to remodel old box cars and coaches for camp car service, and in the past living conditions sometimes suffered. During war years there was little chance for betterment and material shortages still plague most programs for improvement. However, the characteristic American urge to better living conditions is now reflected in the efforts of progressive railroads to improve the lot of the camp car employee. The various phases of sanitation involved in the construction and operation of camp cars are discussed in detail under appropriate headings below.

General

The passenger car shortage continues and responsible officers are still reluctant to release coaches from revenue service until completely worn out. For this reason, the majority of units now being converted to camp car use are box type freight cars that require almost complete rebuilding. To supplement these, a number of railroads have recently purchased second hand troop sleepers and kitchen cars from the War Assets Administration.

Camp car outfits are now carefully designed to suit the specific requirements of the force that is to occupy them. The small, 8 to 16-man forces are usually housed in three

cars, two of which are devoted to sleeping, washroom and recreation and the other to cooking and eating. Large 20 to 100-man forces occupy a correspondingly larger number of cars with varying arrangements as to sleeping, eating and recreational facilities. In some cases, these large outfits are provided with special cars entirely devoted to wash room and shower bath equipment. This simplifies car reconstruction work in that plumbing fixtures can be eliminated from the sleeping cars. However, the present trend seems to be toward having each sleeping car fully equipped, including wash and recreational facilities, so that it can be used in either large or small outfits as a self contained unit.

Living and Recreation Space Requirements

The tendency in the past was to crowd as many men as possible into each car. Old 1920–1930 drawings show 16 to 20 men quartered in 9-ft. by 70-ft. coaches and 12 men in 9-ft. by 40-ft. box type cars, or an average of one person for every 30 sq. ft. of floor space. Present day standards on the other hand seldom call for more than 12 men to be housed in 9-ft. by 70-ft. coaches and from 4 to 8 men in 9-ft. by 40-ft. box cars or an average of about 50 sq. ft. per person. In this connection, U. S. Army Medical Department regulations call for a minimum of 60 sq. ft. of floor space per person in barracks as one means of restricting the transmission of respiratory diseases. During the war, with barracks space at a premium, this minimum space requirement was at times temporarily reduced but never to less than 40 sq. ft. per person.

In addition to allowing more space for sleeping, most railroads now provide recreation rooms equipped with writing tables, card tables and reading lounges for each camp car outfit.

Heating, Ventilation and Lighting

In the past, heat for camp cars was usually furnished by one or two coal stoves and ventilation consisted of the natural interchange of outdoor and indoor air through openings in walls. Some cars were wired for electric lights which could be used only when outside electrical connections were available. Kerosene lamps however were the main standby for light.

In line with other health and comfort improvements, current standards usually call for the following:

1. Coal or oil-fired, hot water heating units with adequate radiation to provide even temperature throughout the car.
2. Roof and wall ventilators in sleeping cars; exhaust fan ventilators for kitchen and dining cars.
3. Windows so located as to provide adequate summertime ventilation for both top and bottom bunks. Windows cased and flashed overhead.
4. Car walls and ceiling smooth lined and insulated for warmth in winter and against excessive heat in summer. Floors covered with linoleum or its equal.
5. Bunks separated and otherwise located to provide maximum space between sleepers.
6. Camp cars wired for electric lights. Larger outfits provided with engine-generator sets.

Drinking Water

In most cases, the procurement of potable drinking and cooking water as well as wash water for camp car use, is a matter of carrying it from the nearest available source, which may be a railway owned supply or a well at a nearby farm house. In bunk cars, the drinking water is dispensed from spout type water cans and tin cups. The dining cars usually have water coolers with a spigot outlet and with ice added

direct to the container. The kitchen cars are necessarily equipped with potable water storage tanks, usually filled by bucket, but sometimes by hose when proper outside water connections are available.

The drinking water is carried to the men at work in containers of various sizes, sometimes in barrels on a motor car and sometimes in smaller vessels, depending on the size of the force, to be further distributed by water boys using buckets and tin cups. Ice is added to the water in summertime when availale.

In some of the arid and sparsely settled western states, camp car outfits must be set out for long periods of time in areas where there is no convenient source of potable drinking water. Here it becomes necessary to supply the needs either by drilling wells or by pumping water from a nearby stream and purifying it by settlement and chlorination. In this connection, at least one western road has considered the feasibility of using small water purification units similar to those used by the U. S. Army, which consist of a 15-gpm. pressure sand filter connected to a gasoline engine-driven centrifugal pump providing 55 gpm. at 50-ft. head, mounted on skid frame, with an alum solution feed into suction side and a belt-driven hypochlorinator pump connected to the discharge. Although difficult to control, the alum dosage, if properly operated can deliver reasonably clear water.

The present general practice of securing drinking water from the nearest available source does not permit much, if any, control of the bacteriological quality of the water, as there is no practical way for camp car employees to test its potability in the field and the water is seldom obtained from certified supplies. Also, the present methods of storing and dispensing drinking water in bunk cars and in the field are not too good from a sanitary viewpoint, as it is impossible to transport drinking water in buckets without danger of contamination from careless handling. The placing of ice directly in the water also adds to hazards. In this connection, one major eastern road is now installing coolers in its camp cars, similar to those used in its passenger coaches. This cooler has a separate compartment for the ice and a recessed spigot outlet.

Inspections of equipment and procedures and interviews with members of various camp car outfits indicate that the principal objection of the present method of dispensing drinking water is the use of the common tin cup. One suggested remedy for this is to provide each employee with a personal folding drinking cup.

Another scheme for the elimination of the common tin cup is to furnish paper cups in special sanitary holders, these cups to be used with antipollution type water cans. This was tentatively tried out by an eastern railroad, which provided two of its large extra gang forces with special insulated water cans fitted with paper cup holders and recessed spigots. After a short trial, this equipment was discarded by the forces using it, who apparently preferred the old water can-tin cup method.

Another recently advertised method that might be adaptable for supplying drinking water to track forces is the so-called portable drinking fountain which is now being manufactured by several companies. It consists of a 4-gal. cylindrical can with an air pump and a bubbler fountain at the top. The principal objections to its use for railway track forces is its dead weight (22 lb.) which added to the weight of the water makes it an awkward load to be carried by hand, and the fact that approximately half of the water is wasted in the process of drinking from the bubbler. It is possible however, that this equipment might be satisfactory enough for a gang of 6 to 12 men who work close to their motor car or truck, in which case the drinking water outfit could be left on the conveyance.

Washing and Bathing

Washing facilities on the average camp car consisted of tin wash basins on a stand to which water was delivered in buckets, or in some cases from overhead tanks. Hot water for shaving had to be heated on the flat top caboose stove provided for this purpose or carried from the kitchen. These cars seldom had shower bath facilities and any bathing was done in a portable tub or out of a bucket.

New standards contemplate that bunk cars be equipped with shower baths, hot water heaters, hand or engine-operated pumps to fill water storage tanks, gravity or pressure water distribution systems and modern porcelain wash basins. Larger forces are being equipped with water tenders and a motor or gasoline engine-driven pump to provide water pressure. The piping system of these outfits is designed to interconnect cars.

Kitchen and Dining Car Facilities

Many railroads are now taking steps to improve their camp car dining service by installing modern refrigeration and food storage facilities, metal covered kitchen tables, two compartment dish washing sinks, exhaust fan ventilators, linoleum floors, etc., in their kitchen cars and with appropriate modernization of the dining car equipment. Although not strictly matters of sanitation, these items concern the health and welfare of the employees and are mentioned for this reason.

Waste Disposal

The usual practice is to sweep dust and trash from bunk cars on to the right-of-way and to collect empty tin cans and garbage from kitchen cars in old lard cans and carry them to an appropriate place for burial. Sometimes nearby farmers will call for and take away the edible garbage for their hogs.

Field inspections indicate that regular garbage cans with lids are seldom used and the reason given in most cases is that they were never furnished. As a result, the garbage is often carelessly handled and left exposed to attract flies and roaches. Although a few roads have made a point of furnishing standard garbage cans, together with instructions regarding the proper handling and disposal of garbage, the majority of camp car outfits still carry on with the old procedures.

Toilet Facilities

The proper disposal of human excreta from railway cars has always been a problem and camp car outfits are no exception. Up until about 20 years ago, the almost universal practice was to carry along one or more collapsible frame privies with each outfit. When cars were parked in yards or near stations, the men were supposed to use the permanent sanitary facilities therein provided. At isolated locations, pits were dug in appropriate places and the privies set up over them for the duration of the stay. The sanitary requirements for the installation and maintenance of this type of equipment are described in the Proceedings Vol. 34, 1933, page 97–99, and mention is made of them on page 13–75 of the Manual.

Observance of all the sanitary rules regarding the construction and maintenance of a pit privy requires knowledge and concern that the average extra gang foreman does not ordinarily possess. Due to pressure of other work the erection is frequently neglected where this equipment is really needed and the employees are required to walk considerable distances to find permanent existing facilities or to seek a more or less secluded spot near the camp cars, and the latter alternative usually chosen.

To eliminate the unsatisfactory conditions incident to use of the portable pit privies, several major railroads in recent years have installed waterless chemical toilets on their camp cars. These consist of a toilet bowl set in the car with a straight drop into a

retention tank which is suspended underneath the car. The bowls and tanks are vented through the roof and the bowl units are enclosed in tight compartments with close fitted doors for odor control. The proper operation of these toilets requires that the retention tank be emptied periodically and recharged with flake caustic soda. The chemical reaction produces a liquid which may freeze unless the tank is insulated. Most units require emptying about once a month and this is usually accomplished by digging a hole in the ground along side the car and directing the liquid sewage into it.

According to information available to your committee, several railroads have tried this equipment and their representatives have reported qualified satisfaction with its use. However, they all mention the necessity for adequate supervision to enforce proper operation and care of the equipment.

The commercially manufactured waterless chemical toilet is intended for use in houses and its adaptation to camp cars usually requires that the size and shape of the retention tank be changed to suit clearance requirements under the car. The bowls, tanks and vent pipe can be purchased but the insulation and hangers for the tank have to be designed and installed by the railway.

Either the pit privy or the waterless chemical toilet, properly constructed and maintained will satisfy the federal regulations, state codes or village requirements that apply. Both systems have objectionable features but to date no better practical method of sewage disposal from camp car outfits has been devised.

Insect Control

Many railroads in the south face a serious problem in the wide spread prevalence of malaria. This insect borne disease does not affect the northern carriers so much, but in both the north and the south, railway camp car outfits are more or less afflicted with pest insects of various kinds, the most common being bed bugs, roaches and non-malaria types of mosquitoes, as well as that principal transmitting agent for intestinal diseases, the fly.

Malaria among railway employees became such a serious problem that several southern carriers years ago instituted special sanitary organizations whose principal duty was malaria control. To review the problems encountered, methods employed and success achieved would require more space than would be consistent with this report. It should be mentioned, however, that the results were usually in direct proportion to the ability of the organizer and to the moral and financial support received from the management. One road has been rewarded by savings in railway hospital expenditures alone amounting to over 200 percent of the cost of the malaria control work.

In general, insect control in camp car outfits in the past has consisted of:

1. Screening of door and window openings.
2. Daily use of insect sprays and repellents.
3. Periodic fumigation of cars with gaseous cyanogen compounds.

Owing to the hazard involved, it has been common practice to issue a circular letter or directive giving specific instructions for the use of hydrocyanic gas and enumerating all the precautions that should be taken to prevent injury or loss of life. The presence of a safety inspector is also usually required and even though dangerous, hydrocyanic gas fumigation, due to its efficiency and the absence of bad after effects, has been for many years the principal method of controlling bed bugs in camp cars.

Late in 1945 there became available to the public, the new war developed insecticide dichloro-diphenyl-trichloroethane, popularly known as DDT, which has the remarkable ability to kill a wide variety of pest insects even when applied in very small quantities.

It is also unique in that it will kill many insects that walk on it, weeks and months after it has been applied to a surface.

After considerable study of literature issued by the U. S. Public Health Service and other governmental agencies, several railroads in 1946 inaugurated research programs of their own which have continued into 1947. From the information available on this subject and from the results already achieved, your committee believes that DDT is superior to any other agent for controlling insects, particularly bed bugs, in camp cars and for the following reasons:

1. One application of DDT will greatly inhibit the activities of pest insects for from two to four months, whereas most other types of insecticides or fumigants are effective for but a few weeks.

2. The use of DDT is not particularly dangerous to humans as is the case with all gas fumigants.

3. DDT is easier to apply and less expensive than most other insecticides. Its application does not require that the car be vacated, whereas gas fumigation precludes occupancy for at least 24 hours.

The DDT insecticide itself is a fine white crystalline powder. It is almost insoluble in water but is soluble in kerosene, xylene, fuel oil, etc., and can be used in a number of forms such as oil solutions, suspensions in water, water emulsions, and a dust dilution or a smoke. The recommended dilution for use in camp car work is a 5 percent DDT spray and a 10 percent DDT powder. Most railroads now using DDT prefer the 25–30 percent emulsion concentrate for the follwing reasons:

1. There is less bulk to be handled and shipped by the stores department.

2. The cost of the finished water diluted emulsion spray is appreciably less than for the kerosene base type.

3. There is practically no fire hazard involved in using the water diluted emulsion, whereas there is definite danger of causing or spreading fires with the kerosene or oil sprays.

4. There is less physical discomfort and less danger of injury to the health of the men doing the spraying.

5. The water diluted emulsion sprays do not have disagreeably persistent odors as does the kerosene type.

6. The water diluted emulsion sprays appear to be equally effective and as long lasting as the kerosene type.

Although easy to apply, the assembly and care of DDT spraying equipment, the preparation of the solution, technique of spraying, etc., require a certain know how and should be done by trained personnel. Roads now using DDT extensively have designated either system or division men to organize and supervise the work. The technique of spraying, descriptions of equipment required, etc., are outlined in many trade and public health publications. Probably the one best adapted to camp car service is an 11-page circular entitled "Use of DDT—Interstate Carriers, Land and Air," issued by the U. S. Public Health Service, Sanitary Engineering Division, Washington, D. C., under date of May 1, 1947, which may be purchased for 10 cents.

Sanitary Control

The basic responsibility for sanitary control is not always clearly recognized. On most roads the chief engineer exercises general supervision over camp car outfits with the division engineer directing operations within his province. The chief engineer's

responsibility usually includes the design for construction or reconstruction of the camp cars. Opportunity is here provided to review for adequacy as to space requirements, heating and ventilation, wash room and toilet equipment, recreational facilities, screening, etc., and to incorporate desired sanitary improvements into the construction.

The foreman in charge of the work is usually the man directly responsible for conditions at the site, and many cases of poor sanitation can be attributed in part to his lack of knowledge of this subject and to lack of interest.

From information submitted to your committee, it would appear that there are few roads that now have a comprehensive sanitary control program which provides for routine sanitary inspections of their camp car outfits or for instruction of the local personnel in the fundamentals of hygiene.

Your committee therefore suggests that for efficient sanitary control work, a definite policy must be adopted. The initial step could be the publication of a circular in which the departmental responsibilities from top to bottom are noted and in which the rules of sanitation for camp cars are set up for specific application.

Report on Assignment 6

Silica Scale Prevention

Ray McBrian (chairman, subcommittee), W. M. Barr, J. J. Dwyer, F. L. Guy, E. C. Harris, W. B. Leaf, W. A. McGee, E. R. Morris, H. M. Schudlich, R. M. Stimmel, J. E. Tiedt, C. P. Van Gundy.

This is a progress report, presented as information.

The subject assigned to this subcommittee for study is the economics of silica removal. Previously reported in the Proceedings, Vol. 42, 1941, page 101, by Subcommittee 7 was the assignment of Silica removal from boiler water. It will be the purpose of this assignment to review the previous report and to bring up to date within the scope of the present subject those new processes developed for silica removal.

The economics value of silica removal depends upon those economic factors which affect actual operation and result in excessive maintenance costs, delays and safety of operation.

In low pressure boilers (locomotive and stationary plants) scale of any type was to be avoided primarily because of waste of fuel, corrosion pits under scale and clogging that retarded circulation. With higher pressure boilers and increased circulation rates, the use of flash boilers on diesels, and the advent of the steam turbine in the railroad field it is necessary to maintain the heating surface in such condition that heat transfer is not retarded. Silica scale or combinations of silica scale even in comparatively minute amounts is exceptionally effective in retarding heat transfer and can result in severe localized overheating.

It has been found that overheating of side sheets with resultant deformation and cracking can occur in a very few months on the higher pressure locomotive boilers and require firebox side sheet renewal due to a thin silica scale, or a combination of silica scale with other relatively thin scale formations and the resultant retardation of heat transfer. A typical example is shown in Fig. 1.

In some localized territories with waters of very low hardness and low silica content this problem of thin scale formation and the tendency to overheating has been found

Fig. 1.—An Example of Silica Scale.

to be of increasing importance, especially where washout periods have been lengthened and long engine runs instituted. The silica content of these waters may be relatively low, but with the longer period of boiler operation trouble apparently develops from the additive or increasing concentration of silica and its deposition on the evaporating surface. This is also found to occur in stationary boiler operations.

Such conditions can also arise with treated waters using processes which do not effectively reduce the silica content to 5 p.p.m.

High silica waters and low silica waters (under some conditions) may then form silica scale, and with long periods of operation sludge containing silica may be baked on the heating surfaces in effective amounts to retard heat transfer, and thus become an economic problem. Siliceous deposits are more complex the higher the operating temperatures and are generally experienced with an increase in pressure and when higher temperatures are encountered in particular locations because of improper circulation.

Schroder and Berk in the U. S. Bureau of Mines, Bulletin No. 443, state that silica is believed to play a part in accelerating embrittlement cracking in sodium hydroxide solutions at the higher temperature ranges of operation. This warrants consideration for silica reduction where processes are available.

Briefly the economies for silica removal based on operating conditions seem to depend upon the following:

1. Overheating of firebox side sheets due to thin silica scale occurring on long engine runs with lengthened washout periods, locomotive coal and oil fired, boiler pressures over 250 lb.
   (a) On territories of natural low hardness water.
   (b) On territories where treated water is used.
2. Reduction of silica as a means of reducing embrittlement tendencies in treated waters.
3. Prevention of silica scale deposits in flash boilers.
4. Prevention of silica scale in high pressure stationary boilers.
5. Use of steam turbine locomotives requires silica deposit removal on turbine blades.

There are several methods of removing silica from boiler feedwater or treatment within the boiler for the purpose to render it harmless.

The previous report of the committee, mentioned above, covered methods of internal treatment and external treatment. (1) By absorption of alumina floc, formed from the action of sodium aluminate and alum. (2) Chemical reaction with magnesium at temperatures near the boiling point. This method can only be used in hot process softeners, or as internal treatment, together with tannin, starch, and other materials. (3) Absorp-

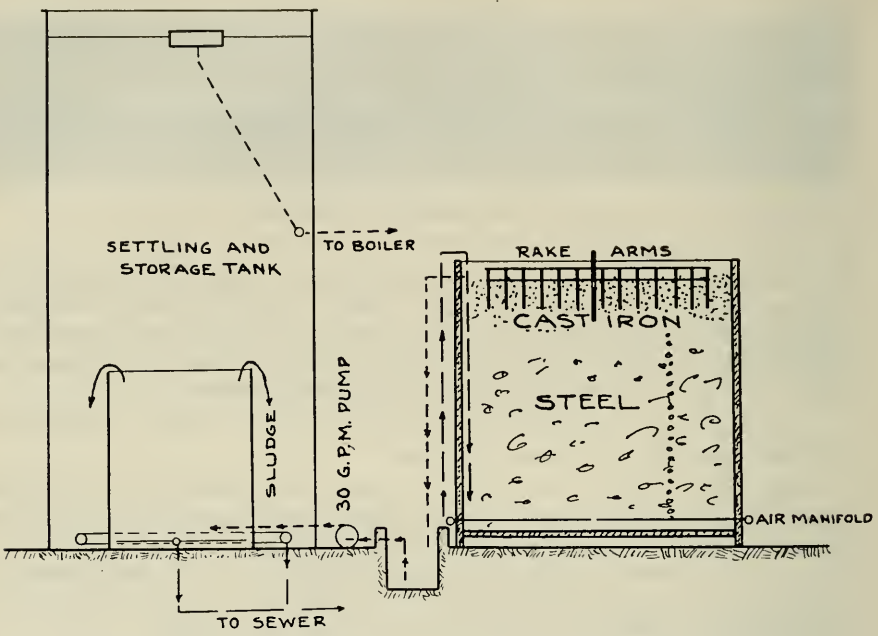

Fig. 2.—Diagram of Rusting Iron Process for Silica Removal.

tion at normal water temperature on magnesium hydroxide floc, using dolomitic lime. The magnesium requirements are roughly three times the silica to be removed. (4) Absorption at normal water temperatures on hydrous ferric oxide floc, using ferrous sulfate or ferric chloride with alkaline materials. The iron salts are relatively high in cost, and yield chlorides or sulfates to the water. (5) Internal treatments using phosphates, glucosides, etc.

Newly developed processes for silica removal are as follows:

A newly developed method for removal of all silica as well as other dissolved solids is that of compression distillation. Such a process might be utilized for small requirements as for flash boilers. The process consists essentially of a boiling chamber called the evaporator, a heat exchanger used to preheat the incoming feed water and cool the condensate and blow down, a vapor compressor which adds heat to the vapor for producing distilled water, together with various motors, a pump and the control equipment.

These units are powered by either electric power or diesel fuel oil. In distillation, heat is consumed principally in converting the liquid to a vapor; this heat is later released when the vapor condenses back to a liquid. In this compression system the heat released is recovered by using it to boil the incoming liquid.

Fuel consumed by this method is stated to be lower than any other self contained similar units. For a diesel engine-driven unit an average of 5 to 8 gal. of diesel fuel per 1000 gal. of water distilled is consumed. For the electrical driven units 50 to 200 kw. per 1000 gal. distilled is required.

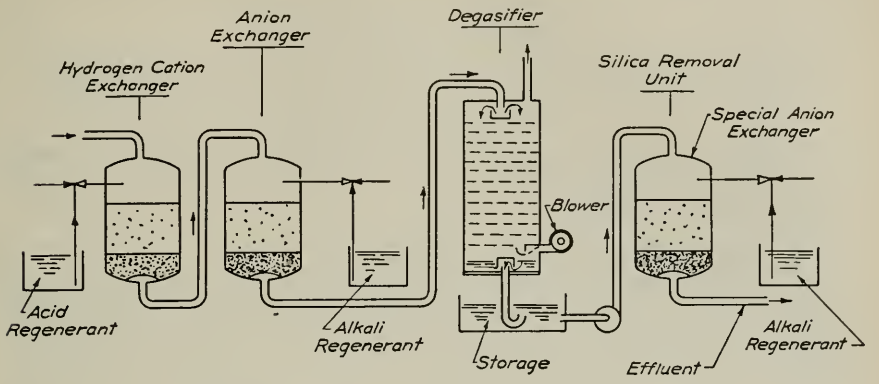

Fig. 3.—Diagram of the Hydrofluoric Acid Process.

Another new process for removing dissolved silica from water consists of the rusting of iron in the form of cast iron wheel borings in the presence of the water to be treated. The hydrous ferric oxide thus formed absorbs the silica by physical action. The ratio between the iron rusted and the silica removed depends upon the initial silica content of the water and the degree of silica removal. Roughly, it is estimated, a pound of iron oxidized to the ferric state will remove a pound of silica. The process will be low in cost and has the added advantage of not introducing further dissolved solids in the water. A diagram of a plant designed to remove silica from boiler water by this method is given in Fig. 2.

Another development applies the principles of demineralizing to the removal of silica from raw boiler feed water. This development employs the standard demineralizing equipment consisting of the hydrogen unit followed by the anion exchange unit. To accomplish the removal of silica, a fluoride, such as sodium fluoride, is added to the raw water entering the hydrogen zeolite unit. Here, the fluoride is converted into hydrofluoric acid by a resin type of acid-regenerated cation exchange material.

The hydrofluoric acid combines with the silica to form fluorosilic acid. The fluorosilic acid together with the acids formed from the hardness in the raw water are removed by an alkali-regenerated anion exchange resin of high capacity. The schematic diagram for this method of silica removal is shown in Fig. 3.

Conclusions

The amount of soluble silica which may be present in boiler water without harmful effect varies. The most general rule is that the higher the boiler pressures the lower the silica content in the boiler water must be. The methods of solution and the economies will depend upon the individual conditions encountered.

Report on Assignment 7

Requisites of Water and Wetting Agents used in Washing Passenger Train Cars

G. E. Martin (chairman, subcommittee), R. C. Bardwell, W. M. Barr, I. C. Brown, R. W. Chorley, R. E. Coughlan, B. W. DeGeer, E. M. Grime, O. E. Mace, Ray McBrian, W. A. McGee, G. F. Metzdorf, H. M. Schudlich, R. W. Seniff, H. M. Shepard, R. E. Wachter.

This is a final report, presented as information.

In considering this subject it has been assumed that the washing of passenger train equipment will be done by mechanical washers. The committee has proceeded on this assumption, not because the mechanical washers will require a change in the character of the water or wetting agents for this purpose, but because mechanical washers are largely used. It has been noted, however, that various designs of mechanical washers affect the results obtained.

Since there is so much to know of wetting agents and the results that can be secured from their use, either separately or combined, it seems appropriate to make some statements concerning their general properties. Wetting agents are substances which are added to surface coatings to increase spreading and penetrating action. In general, wetting agents are made up of more or less complicated molecules composed of two essential parts. One part is termed "hydrophilic" and is the portion that draws the agent into the water. The other part of the molecule is termed "hydrophobic" and it tends to leave the water and attach itself to or dissolve in an oil or other nonpolar medium. Wetting agents belong to a class of materials called "surface active agents," and among their properties is their ability to lower surface tension and interfacial tension. The effect of surface active agents on surface tension is influenced by the presence of water-soluble salts, such as sodium chloride and sodium sulfate. The action is further materially affected by the pH value of the solution. Coupled with low surface tension in wetting are such properties as solubility and the condition of the surface. Experiments with clean surfaces do not compare with results secured under the conditions usually found in the field. The character of the soil on the surface will govern the type of agent which may be used to reduce the surface tension of a liquid in contact with that surface. Soap is an effective wetting agent unless the metal ions in the water or on the surface are sufficient to destroy its value. Alkalies, phosphates and silicates are less costly and in many cases more useful.

The best wetting agents are not under all conditions good detergents, but a good detergent must have good wetting properties. It is thought that most detergency occurs by the reduction of interfacial tension, followed by emulsification of the wetted soil. In this latter step the mechanical action of agitation is very important.

Type Cleaner or Wetting Agent Used

A satisfactory response was received from committee members to a questionnaire relating to the present practice of various railroads on this subject. The information obtained indicated that of the 12 railroads reporting, 2 did not have mechanical washers; and 7 reported the use of a certain proprietary cleansing compound which will be designated as cleaner "A" for further reference. One of these seven also used another type that will be known as cleaner "B." One other road used a type which will be known as cleaner "C." One road uses an oxalic acid solution and this will be known as cleaner "D." Another road reported a combination of wetting agents which will be known as cleaner "E."

An analysis of cleaner "A" indicated a composition as follows:

	Percent
Water	9.16
Organic matter	12.55
Sodium bisulfate (acid sodium sulfate)	77.86
Undetermined	0.43
Total	100.00

The organic matter was 10.29 percent alcohol soluble fraction, which is a brown liquid with a pine oil like odor. This probably had some wetting and dispersing benefits but was probably used as a deodorant and an inhibitor. Also, 2.26 percent of the organic matter was of chloroform soluble material which was undoubtedly a wetting agent, but it was not identified. The pH value of a 1 percent solution is 1.7.

No analysis was made of cleaner "B" and since it was used at only one point it did not appear to be very popular.

Cleaner "C" is used by one of the larger railroads and that road's representative reported that this material was essentially acid sodium sulfate to which a wetting agent has been added.

Cleaner "D" is used by one of the larger railroads and the particular washer in which its use was observed handles approximately 125 passenger cars per day. This cleaner is used only on head-end cars or particularly dirty cars, while clear water is used on cars not so dirty. Satisfactory results are secured by this practice. The operator of the machines estimated that the cleaner was not used more than once each 30 days on regular equipment.

The engineer of tests of this railroad states that cleaner "D" consists of 32 lb. of oxalic acid crystals and 5 lb. of a wetting agent dissolved in sufficient water to make 50 gal. When washing is done with mechanical washers this solution is diluted by adding one barrel of water to two barrels of the concentrated solution. Approximately 4½ gal. of the diluted solution is used on each car cleaned when acid is used. However, this amount may be varied as is deemed advisable, depending on the condition of the cars.

The concentrated solution is practically saturated and should be held at a temperature of 60 deg. F. or above to prevent the formation of crystals, as may occur if the temperature is lower. In the diluted mixture, crystals will form on cooling below 30 deg. F. and will redissolve at 32 deg. He also added that any well known wetting agent will serve satisfactorily with the oxalic acid solution provided it is selected for use in an acid solution.

Cleaner "E" has not actually been used for this purpose but considerable work has been done by the reporting road to find the most suitable wetting agents, and the reports of laboratory experiments indicate that the combination of 2 oz. of sodium metasilicate and ½ oz. of a proprietry compound per gal. of water resulted in the best combination of a wetting agent that had been tried up to this time. This road's representative stated that a large number of proprietary cleaning compounds had been tested and none of them was found entirely satisfactory.

There are many agents that might be used, as many chemical manufacturers have developed wetting agents that would be suitable for this purpose.

Water Requirements

From reports received and from observation it is noted that 100 to 300 gal. per min. is required for washing. The speed of the car through the washer is from 60 to 90 ft. per min. and the pressure used varies from 23 to 110 psi. Water from city supplies is

generally used. One road reports the use of a well supply which is a sodium bicarbonate water. No road reports the heating of cleaner fluids or water for this purpose.

The cleaner, or wetting agent, is applied from 30 ft. to 160 ft. in advance of the rinsing of the cars. The solution is applied by pump or air pressure and in some installations brushes are provided for agitation at that point as well as just prior and during the rinsing of the car. The volume of water available for rinsing is quite important. One road reports a second rinsing of the cars as they are returned to the yard, the speed through the washer being approximately 200 ft. per min. The second rinse, if given, just before drying occurs, should be beneficial in preventing streaking. The streaking of windows is a definite problem in that the draining of dirty water from cracks if permitted to dry on the windows is very undesirable.

The reports received indicate that the cleaners used have no injurious effect on the paint, stainless steel or aluminum trim of the coaches. Since an acid type of cleaner is in general use it would seem advisable not to use excessively high alkaline water for this purpose. It does not seem advisable to use softened or antiscale treated water for this purpose, and certainly water retained from blowing down boilers would be unsuitable.

Conclusions

There are so many types of wetting agents and so many factors that affect the properties of a wetting agent that considerable study and trial are necessary to secure the best materials for this purpose. Roads operating through a section of the country where the dust would be largely carbonates would require different treatment from equipment operating through a sandy country where the dust would contain considerable silica. These factors should be taken into consideration before deciding on the wetting agent that would be most effective for car cleaning.

Report on Assignment 8

New Developments in Water Conditioning for Diesel Locomotive Cooling Systems and Steam Generators

M. A. Hanson (chairman, subcommittee), I. C. Brown, B. W. DeGeer, R. S. Glynn, E. C. Harris, T. W. Hislop, Jr., H. M. Hoffmeister, G. A. Little, O. E. Mace, G. E. Martin, Ray McBrian, H. L. McMullin, A. R. Nichols, H. M. Schudlich, R. M. Stimmel, T. A. Tennyson, J. E. Tiedt, R. E. Wachter, E. L. E. Zahm.

Your committee submits the following progress report as information.

Diesel Locomotive Cooling Systems

The previous recommendations made by your committee for the prevention of corrosion, scale and sludge in diesel cooling systems are still believed to be valid and the best known practice. These recommendations are found in the Proceedings, Vol. 48, 1947, pages 209–210.

A diligent search has been made for a substitute for chromates as a corrosion inhibitor, because chromates are relatively expensive and have been difficult to secure in adequate quantities. This search has been unsuccessful in developing any adequate substitute.

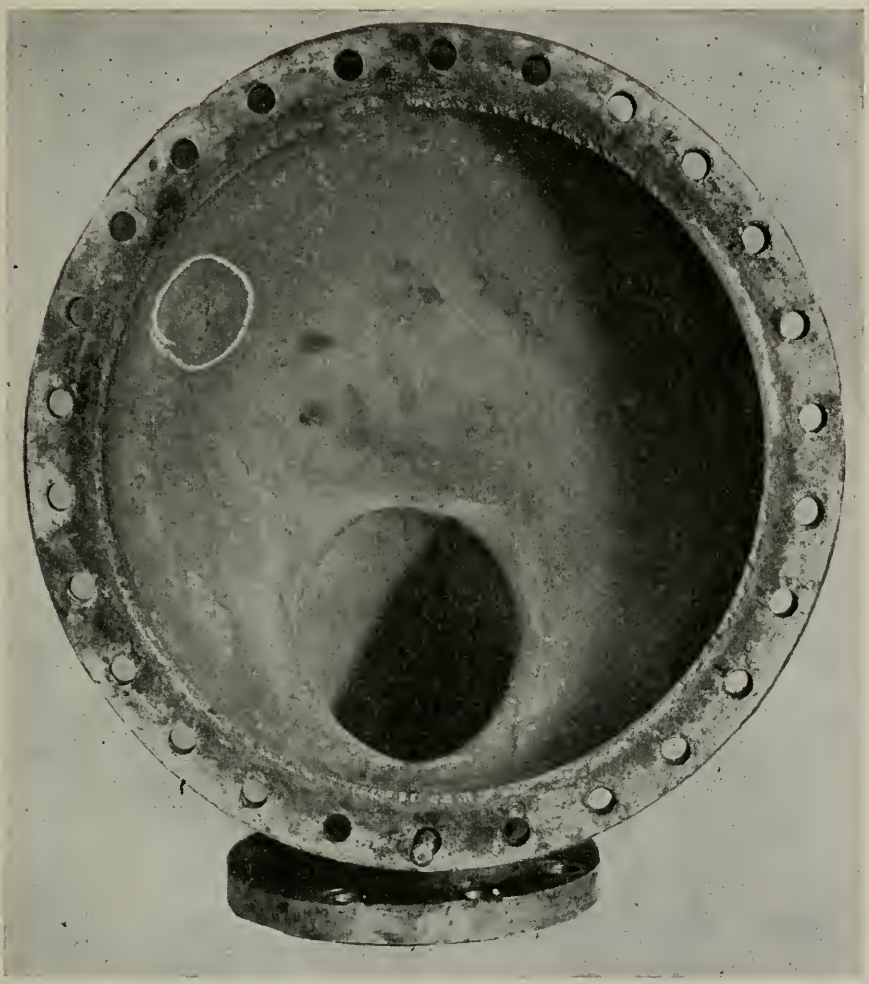

Fig. 1.

It is doubtful if the aluminum portions of diesel cooling systems can be adequately protected against corrosion under all conditions. Fig. 1 shows an aluminum oil cooler head corroded after 9 months' service. The remainder of the cooling system was in excellent condition. Fig. 2 shows a cylinder liner removed from this same locomotive after the same service which is free from either scale or corrosion. The cooling water treatment and control were good on this locomotive during the entire time these parts were in service.

The extreme difficulty of adequately protecting aluminum from corrosion in a diesel cooling system is due to the position of aluminum in the electromotive series. There is a potential difference of 1.61 volts between aluminum and copper and 0.93 volts between aluminum and iron.

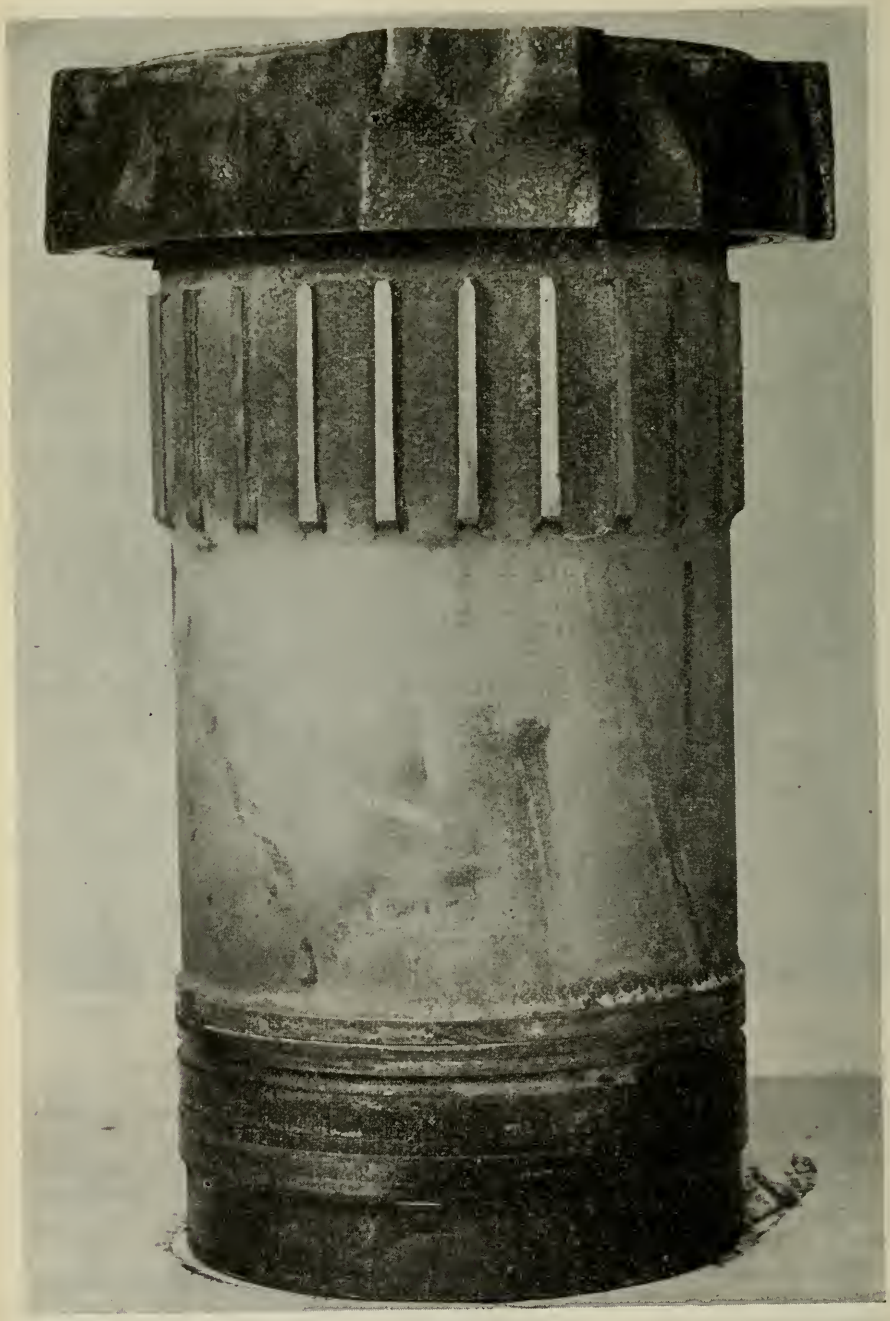

Fig. 2.

The locomotive builders are increasingly recognizing this difficulty and are making progress toward the elimination of aluminum from the cooling systems. One of the major locomotive builders has seen the adverse effects of incorporating aluminum in the cooling systems on its locomotives and has eliminated the use of aluminum in contact with cooling water. Another major locomotive builder is using a special corrosion resistant aluminum alloy for the parts in contact with cooling water. The only justification for adopting a relatively expensive alloy in place of a more corrosion resistant ferrous metal is to save weight if the reduction of weight on axles is of such importance as to make it necessary.

Considerable difficulty is being experienced in maintaining the desired concentrations of corrosion inhibitors at all times. This is particularly true on locomotives which have seen considerable service and which for one reason or another are not maintained in a leak free condition. The normal cooling water consumption of a road locomotive, free from leaks is relatively small, frequently not exceeding 5 gal. per day. However, when leaks develop, the consumption of cooling water can become so great that most of the corrosion inhibitor is lost in two or three days.

This is of prime importance, since if the alkaline chromate concentration falls below the critical level of approximately 4 gpg.* the rate of corrosion is accelerated beyond that experienced with no treatment. No adverse effects to the cooling systems have been observed from treatment in excess of that recommended, but the cost of treatment is increased due to the increased loss of chemicals when loss of cooling water occurs.

In addition to damaging the cooling system itself inadequate cooling water treatment also adversely affects the life of other parts of the locomotive engine. The resultant increase in oil temperature due to a fouled cooling system tends to increase the rate of oil break down, to hasten bearing corrosion and to increase the tendency toward sticking piston rings. H. W. Luetkemeyer, chief engineer, Cleveland Graphite Bronze Co. in the Journal of the Society of Automotive Engineers, July 1947, pages 49 and 60, in discussing bearing maintenance states that "the vehicle engineer cannot solve problems of operators who permit scaling in water jackets, lack of coolant, and other careless practices in maintenance."

Although not directly the subject of this committee, but very closely related to it is the problem of water conditioning for other internal combustion engines than those found in diesel locomotives. One railroad, in less than a year's time, after installing engine-driven air conditioning compressors and train lighting generators experienced difficulty in maintaining the engines due to overheating. The adoption of water conditioning similar to that used on its diesel locomotives, together with adequate analytical control, overcame these operating difficulties in a very short time. Therefore it is believed the practices used for water conditioning for diesel locomotive cooling systems should be extended to other internal combustion engines such as air conditioning and train lighting engines, trucks, busses, shop tractors and automobiles.

Since it is known that the alkaline chromate type inhibitors, used in the proper concentrations are effective in accomplishing the desired results, the actual realization of these results is dependent upon maintaining the necessary analytical control. With a large number of units in service the analytical control must of necessity be exercised by the service forces.

A colorometric analytical procedure has been developed for this purpose. It consists of a chemically impregnated blotter. When one drop of cooling water is placed on the blotter, a definite color develops. The color is then compared with a standard reference chart.

* Grains per gallon.

By this method a quite definite evaluation of the amount of chromate present in the cooling system can be quickly determined by the maintenance forces. This test also serves as a permanent record of control since the records of chemical additions may be entered on the spot test card and filed for future reference.

It is believed a simple, quick test of this nature, suitable for use by maintenance forces, is a requisite in any effort to obtain the desired cooling system conditions.

Steam Generators

As noted in the previous report of this committee, Proceedings, Vol. 48, 1947, pages 210–215, only one type of steam generator has been considered in this report. A new type of steam generator has now been developed and placed in service, but to the present time no definite data have been accumulated upon its water conditioning requirements. It is hoped this can be done during the coming year.

During the past year a series of tests was conducted which have added considerably to our knowledge concerning the feed water requirements of these steam generators. The following types of treatment were tried.

Demineralized Water.—A two-bed demineralizer was installed by a chemical company at a steam generator manufacturer's plant for test purposes. The effluent from the demineralizer was post treated with a proprietary tannin, phosphate, soda ash boiler compound and used as feed water for a steam generator. Chicago city water was used as the source of supply for this test.

The steam generator was operated for six weeks after which the coils were removed and sectioned. The coils were clean but showed slight corrosion at the inlet end of the outer coil. Several railroads now have demineralizers in service.

Deaeration.—A steam jet deaerator was installed at a steam generator manufacturer's plant and incorporated in the flow cycle of a steam generator. This deaerator was of such size that it could be installed on a steam generator on most diesel locomotives. This test indicated that reasonably complete deaeration can be obtained by this type of installation.

Internal Treatment With Calcined Potassium Carbonate.—One railroad, operating 25 steam generators for the past year has been treating all the waters supplied to them with calcined potassium carbonate. The potassium carbonate is added directly to the locomotive supply tanks. This method of feeding was adopted since satisfactory proportioning could not be secured by the feeders on the locomotives.

The water supplies for these steam generators are typical midwestern waters varying in hardness from 6 gpg. to 22 gpg. and in total dissolved solids from 7 gpg. to 32 gpg. Sufficient potassium carbonate is added to produce an excess of approximately 30 percent of potassium carbonate in the return water from the steam generator coils.

The reaction between the hardness in the water and the potassium carbonate in the supply tanks is quite rapid, much more so than with sodium carbonate. Samples collected from the locomotive supply tanks, 40 min. after leaving the terminal frequently show as little as 1/3 gpg. hardness. The reaction naturally produces sludge but the sludge is relatively nonadherent, whereas sludge from either sodium carbonate or sodium phosphate is adherent at the temperatures encountered in the engine storage tanks and feed water appurtenances. Potassium carbonate treatment has not resulted in scaling of any of the controls, feed pumps, or supply tanks. The supply tanks are flushed monthly to remove the accumulated sludge. If a small amount of scale should adhere to the supply tanks it can be readily removed by an inhibited acid rinse.

Fig. 3.

The return water from the steam separator is highly concentrated, frequently having 500 gpg. of total dissolved solids, and sometimes as high as 1550 gpg. The usual range of the pH value of the return water is 11.2–12.4. A typical analysis of a return water from the seperator with this treatment is as follows:

TDS.....556 gpg	OH. 111 gpg.
MO.....144 gpg	Hardness 0 gpg.
2P.....255 gpg	pH 12.32
	MO/TDS 26 percent

The results to date with this treatment have been good. Steam generator coil washouts have been extended to 30 days and no trouble with high water pressure has been experienced.

Three sets of coils have been removed for examination. The outer coils show some corrosion at the inlet end and very slight corrosion at the outlet end. Fig. 3 shows sections of the inlet and outlet ends of one outer coil after 12 months' service during which the locomotive made 240,000 miles in passenger service between Chicago and St. Louis. The intermediate and inner coils show no corrosion. The results to date indicate that the life of the outer coil to be expected with this treatment will be two to three years and that of the intermediate and inner coils considerably longer.

Corrosion Control.—Tests were conducted to determine if corrosion of the outer coils could be stopped by pH control. These tests indicate corrosion will occur in the presence of oxygen up to a pH of 12.5. This high pH value in feedwater is not economically feasible. However, the higher the pH value of the feedwater the slower the rate of corrosion. Tests with deaerated water with a pH of 7.5 or above showed no corrosion of the coils.

Locomotive Feeders.—The various types of chemical feeders on the locomotives for proportioning water treatment compounds to the steam generators continue to be a source of trouble. If water treatment is to accomplish the desired results it must be properly proportioned at all times. Scale formed in the coils due to low treatment cannot be

removed by acid washing. Therefore, treatment must be maintained at all times. Fig. 4 shows a set of coils severely corroded and heavily scaled due to the failure of a feeder on a locomotive to proportion the treatment accurately.

The analysis of the scale in the coils is as follows:

Analysis of Scale from Clarkson Type Steam Generator Coil

	Fifth Inside Turn of Inner Coil (That is the coil nearest to fire) percent	*Eighth Inner Turn of the Intermediate Coil* percent
SiO_2	4.65	4.47
CaO	32.32	32.72
MgO	12.83	6.54
SO_3	40.25	49.42
R_2O_3	2.25	2.40
CO_2	8.44	6.08
	100.74	101.63

This scale was practically unaffected by muriatic acid even after 48 hours of contact between the acid and the scale.

Note the small percentages of carbonate. The scale probably existed as calcium carbonate, a calcium aluminum silicate complex, calcium sulfate and magnesium sulfate.

This series of tests indicates that a number of types of water treatment can be used with reasonable success. In addition to demineralized water with after treatment for pH

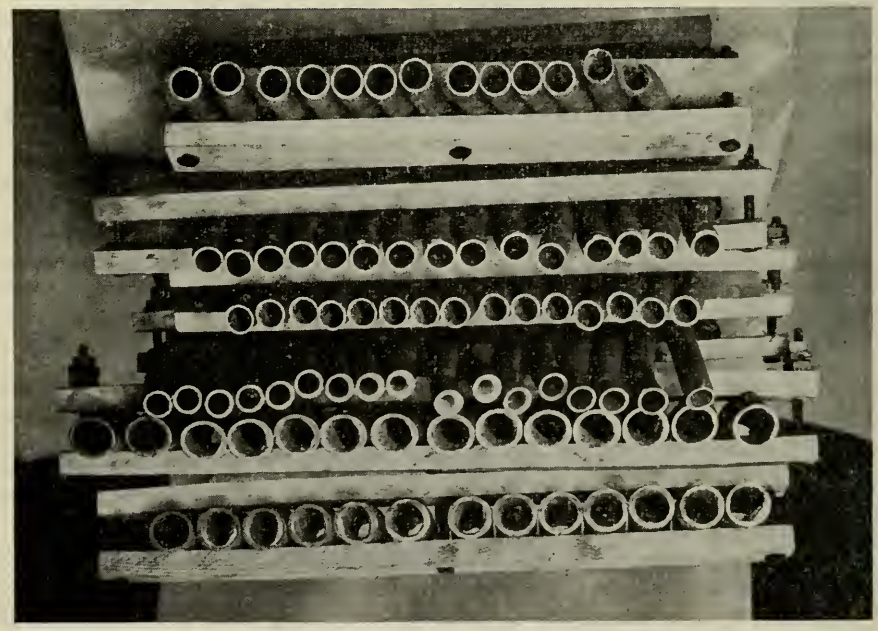

Fig. 4.

control and internal treatment with calcined potassium carbonate it is believed that lime soda treatment or zeolite with after treatment for pH control when necessary can in many instances be used successfully. If corrosion is to be completely stopped, oxygen removal from the feedwater must be accomplished. This can be done by deaeration. The exact type of treatment to be selected will have to be governed by the initial type of water available, the volume of water required, the severity of the service requirements and the existing facilities available.

Irrespective of the type of treatment selected, the proportioning equipment used must be accurate and reliable. This indicates the necessity of supplying treated water to the locomotive in a manner similar to that which is employed in the best steam locomotive practice.

In addition the analytical control must be sufficiently frequent and accurate to ascertain definitely that proper treatment is being maintained at all times. It is believed this can not be done by the maintenance forces but must be done by a properly trained water engineer.

Report of Committee 9—Highways

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C. V. Talley
R. R. Thurston
E. G. Wall
V. R. Walling
R. E. Warden

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including recommended revisions .....page 89

2. Design and specifications for highway crossings at grade over railway tracks, both steam and electric, collaborating with Committee 1, and with American Society of Municipal Engineers, and American Transit Association.

   During the past year your committee has been engaged in the revision of some specifications, the results of which are contained in the report on Revision of Manual.

3. Comparative merits of various types of grade crossing protection, collaborating with Signal Section, AAR, and Highway Research Board.

   No Report.

4. Requisites for location, number and arrangement of automatic signals, automatic gates and auxiliary signs for rail–highway grade crossing protection, collaborating with Signal Section, AAR, and AAR Joint Committee on Grade Crossing Protection.

   No Report.

5. Method of classifying grade crossings with respect to public safety.

   No Report.

The Committee on Highways,
W. J. Hedley, *Chairman.*

AREA Bulletin 469, November 1947.

Report on Assignment 1

Revision of Manual

H. G. Morgan (chairman, subcommittee), H. D. Blake, Bernard Blum, H. F. Brockett, A. P. Button, P. W. Elmore, A. S. Haigh, W. J. Hedley, C. D. Horton, Maro Johnson, R. B. Kittredge, G. P. Palmer, W. C. Pinschmidt, V. R. Walling, R. E. Warden.

This year your committee has completed a general review of all of the Manual material in Chapter 9. Complete revisions of the older specifications on the construction of grade crossings have been prepared by Subcommittee 2 under the chairmanship of R. E. Warden. Some changes and deletions are recommended in other portions of the text and revisions of a number of crossing protection signal plans are offered in order to conform to changes recently approved by the Signal Section, AAR. These changes in signal plans are generally minor in character.

Nine specific revisions are recommended.

Item 1

Delete pages 9–1 to 9–4, incl., and substitute the following:

GENERAL SPECIFICATIONS FOR HIGHWAY GRADE CROSSINGS OVER RAILROAD TRACKS

1948

1. Width of Crossing

Crossings shall be constructed at least 4 ft. wider on each side, measured at right angles to the highway, than the width of the adjacent approach pavement or roadway surface, in order to reduce the hazard of vehicles running off the crossing.

2. Crossing Approaches

The width of embankments and cuts, exclusive of ditches, shall be not less than 24 ft. The roadway surface shall correspond to that of the adjacent highway. The surface of the highway shall be in the same plane as the tops of rails for a distance of 2 ft.

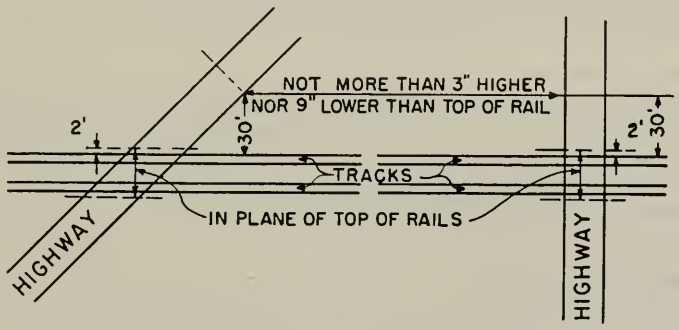

Fig. 1.—Method of Fixing Approach Grades for Highway Crossings as Described in Paragraph 2.

outside thereof; shall be not more than 3 in. higher nor 9 in. lower than the top of the rail at points 30 ft. from it, measured at right angles thereto. (Fig. 1). The grade beyond these 30-ft. points shall not exceed that which prevails in the section of the country for highways of the class under consideration.

3. Drainage

Surface ditches shall be installed. If required, subdrainage with suitable inlets and necessary provisions for clean-out shall be made to drain the subgrade thoroughly and prevent the formation of water pockets. This drainage shall be connected to a storm water sewer system, if available; if not, connecting metal, concrete or vitrified pipes shall be installed to carry the water a sufficient distance from the roadbed. Where gravity drainage is not available a nearby sump may provide an economical outlet, or the crossing may be sealed and the roadbed stabilized by using asphalt ballast or its equivalent in addition.

4. Ballast

If the track at the point of the crossing is not well ballasted, or if the ballast is foul, the ballast and subballast shall be dug out not less than 2 ft. below the bottom of the ties, not less than 2 ft. beyond the ends of the ties and to the first rail joint each way from the crossing, and reballasted with ballast to conform with AREA specifications.

5. Ties

Where feasible 9-ft. treated ties shall be used through the limits of the crossing.

6. Rail

The rails throughout the crossing, and for a rail length on each side, shall be renewed with new rails of the section that is standard in that district, unless the existing rails are of full standard section. Rails shall be so laid to eliminate joints within the crossing. Preferably, the nearest joint should be not less than 6 ft. from the crossing. Where necessary, long rails shall be used or the rail ends shall be welded to form continuous rail through the crossing. Rails shall be double spiked to perfect line, and the track shall be thoroughly and solidly tamped to uniform surface. Rails shall be protected with an approved rust inhibitor.

7. Flangeway Widths

Flangeways 2½ in. wide should be provided on tangent track and on curves of 8 deg. and under, and 2¾ in. wide on curves in excess of 8 deg.

8. Choice of Material for Crossing

When selecting the type of crossing and the material to be used in constructing it, consideration shall be given to the character and volume of traffic using the highway.

The crossing shall be suitable for the class of railway track in which it is located and for the type of roadway surface on the highway it serves.

Included in the Manual are specifications for the construction of crossings of the following types:

Bituminous crossings
Wood plank crossings
Prefabricated sectional treated timber crossings
Precast concrete slab crossings
Monolithic concrete crossings

Item 2

Delete pages 9–5 to 9–7, incl., and substitute the following:

SPECIFICATIONS FOR THE CONSTRUCTION OF BITUMINOUS CROSSINGS

1948

1. Scope

These specifications cover the use of cut-back products, emulsified asphalt and rock asphalt in the construction of bituminous crossings.

See the General Specifications for Highway Crossings over Railroad Tracks to determine the size of the crossing, the construction of crossing approaches and the preparation of the track structure.

2. Foundation

The new ballast shall be thoroughly tamped to a uniform surface level with the top of the ties where emulsified or cut-back material is used. Where rock asphalt is used, additional ballast shall be used to bring the surface to 1½ in. below the top of rail.

3. Materials

Cut-back products shall conform to the requirements of the Aspalt Institute specifications for rapid curing liquid products RC–2. Emulsified asphalt shall conform to the requirements of the Asphalt Institute specifications for medium setting material MS–2.

4. Handling Materials

Bitumens shall be thoroughly mixed before removal from the barrel. Cut-back products contain an inflammable solvent and care should be taken to keep them away from open flames. Emulsified asphalt shall not be exposed to freezing temperatures.

All bituminous mixtures may be used immediately after mixing. They shall be protected from rain. Bituminous mixtures shall not be spread when the temperature is below 50 deg. F. The foundation shall be dry when cut-back mixtures or rock asphalt are applied. The foundation may be damp when emulsified asphalt is applied.

5. Flangeways

Flangeways shall be formed by the installation of an approved material on the gage side of the rail and separators shall be laid adjacent to the outer side of the rail to prevent bituminous mixture from coming in contact with rail. The tops of the separators shall be ¼ in. below the top of rail.

6. Method of Constructing Pavement

(a) When an emulsified asphalt or cut-back product is used as the cementing agent, the following paragraphs shall govern:

Paint Coat.—Surfaces of flangeways and separators in contact with bituminous mixtures shall be coated with bitumen as the primer or tack coat.

Binder Course.—Upon the foundation of ballast and ties there shall be spread evenly a layer of bituminous mixture, the surface of which, after being thoroughly tamped, shall be 1½ in. below the top of rail. The bituminous mixture shall be made in the following proportions:

1 cu. ft. of clean graded stone ¾ in. to 3 in. size
½ to ¾ gal. of bitumen

The materials shall be thoroughly mixed and the stone uniformly coated with the bitumen. This can be done by placing the stone on a mixing board in a layer about 6 in. deep, adding the bitumen, and then raking or turning over the mixture with shovels.

Wearing Surface.—Upon the binder course there shall be spread evenly a layer of bituminous material which shall be thoroughly compacted, preferably with a self-propelled roller. When such a roller is used, the finished surface, after rolling, shall be level with the top of rail but not crowned. When tamped by hand or a hand roller is used, the finished surface shall be from ½ in. to 1 in. above the top of rail to allow for compacting by vehicles. The mixture shall be made on a mixing board in the same manner as the binder course and in the following proportions:

1 cu. ft. of clean stone ⅝ in. to 1 in. size
1 gal. of bitumen

Seal Coat.—A seal coat of clean sand or crushed stone grits mixed with bitumen shall be spread and compacted over the crossing to fill the voids but not to make a layer. It shall be made in the following proportions:

1 cu. ft. of sand or crushed stone grits ¼ in. or ½ in. size
1½ gal. of bitumen

(b) If rock asphalt is used, the following paragraph shall govern:

Wearing Surface.—The rock asphalt shall be shoveled into place on the foundation and raked thoroughly to produce an even surface and an even thickness of 2¼ in. It shall then be compacted, preferably rolled with a self-propelled roller until the entire surface is smooth and free from waves, depressions or honeycombed areas, until all roller or tamping marks disappear, and until the finished surface is level with the top of rail. Particular attention shall be given to thoroughly compacting the rock asphalt adjoining flange guards or separators.

7. Repairs

A small quantity of material shall be stored properly, near the crossing, for the purpose of repairing holes or pockets in the pavement as soon as they appear.

Item 3

Delete the Specifications for the Construction of Rail Type Street Crossings, appearing on pages 9–9 and 9–10.

Item 4

Delete pages 9–11 and 9–12 and substitute the following:

SPECIFICATIONS FOR THE CONSTRUCTION OF WOOD PLANK CROSSINGS

1948

1. Scope

These specifications cover the use of wood plank in the construction of crossings.

See General Specifications for Highway Crossings over Railroad Tracks to determine the size of the crossing, the construction of crossing approaches and the preparation of the track structure.

2. Materials and Installation

It is recommended that creosoted planking and shims or furring strips be used. The accessibility of the various species of wood may determine the kind of timber and the kind of treatment, if any, that is most economical for use by an individual railway. This consideration should be the governing factor in the selection of the material to be used. The timber shall be milled before treatment.

Crossing plank shall be of 8-in. and 10-in. widths, not less than 4 in. thick, and shall be surfaced one side and one edge for uniform thickness and width. Commercial length planking of the most economical lengths for the individual crossing shall be used. The lengths of planks shall be chosen to stagger joints so that no two adjacent planks shall have their intermediate ends on the same tie.

Shims not less than 6 in. in width and of proper thickness to bring the tops of crossing planks in the same plane as the top of running rails shall be provided and securely nailed to each tie. Sawed cross ties shall be used to provide full and even bearings for the shims.

Planks shall be laid with ⅛-in. to ⅜-in. openings between edges. Each plank shall be securely spiked down at its ends and to every other tie, using two boat spikes driven diagonally to prevent heaving of the plank. Plank ends shall be bored for boat spikes to prevent splitting. For crossings where the rail is between 5 in. and 6 in. in height, boat spikes ½ in. by 10 in. shall be used. Where the rail is more than 6 in. in height boat spikes ½ in. by 11 in. shall be used.

Planks may be fastened down with lag screws instead of boat spikes. Where lag screws are used they shall be of same size as specified for boat spikes, but only one lag screw in each plank and in every other tie shall be required. Planks shall be bored for lag screws with holes 1/16 in. larger diameter than that of lag screw, and shall be countersunk for the washers and lag screw heads.

The top of the plank crossing shall be even with the highway pavement. The edges of outside planks shall extend to and may project not more than 1 in. beyond the ends of the ties. If the pavement beyond the track is of concrete, a space of 1 in. shall be provided between the edge of the planking and the pavement. If the pavement is of construction other than concrete, a 4-in. by 18-in. creosoted timber header shall be placed on edge the full length of the pavement to retain it, and a space of 1 in. shall be provided between the edge of planking and the face of the header.

Flangeway guards shall be installed in all important crossings; they shall be either dapped plank, old steel rail balled in, or of some suitable patented type. Metal flangeways shall not be used in track circuited territory.

All outside ends of crossing planks and flangeway guards shall be bevelled not more than 45 deg. from the horizontal to prevent possible damage through being struck by dragging equipment. The outside ends of planks shall not project beyond the shims on which they rest.

Item 5

Delete the material bearing the heading, Proper Vertical Curves on Highways for Grade Separation Projects, appearing on page 9–13.

Item 6

Delete the material on pages 9–14 and 9–15 bearing the heading, Principles for Determining the Relative Benefits to the Public and Railroads from:

Grade Crossing Protection
Elimination of Grade Crossings
Reduction of Traffic on Highway Grade Crossings.

Item 7

Delete pages 9–15 and 9–16 and substitute the following:

THE USE OF CENTER COLUMNS FOR HIGHWAY GRADE SEPARATIONS

Center columns shall be used only when opposing traffic lanes are or can be separated by a median strip extending to the top of the highway approaches or to the next street intersection beyond the top of the highway approach.

Item 8

Delete the words "reaches or" from the second line of Section 5 on page 9–17.

Item 9

Revise the drawings for crossing protection signals and details as listed below to conform with the changes in these drawings recently adopted by the Signal Section, AAR. No functional changes are involved. The changes relate to the manner of showing dimensions, the position of notes, minor refinements in structural details and to the specifications for materials and finishes. The drawings are as follows:

Fig. 902.—Replace Sig. Sec. 1692A with 1692B.
Fig. 903.—Replace Sig. Sec. 1693B with 1693C.
Fig. 903–A.—Replace Sig. Sec. 1691C with 1691D.
Fig. 904.—Replace Sig. Sec. 1651D with 1651E.
Fig. 905.—Replace Sig. Sec. 1652D with 1652E.
Fig. 906.—Replace Sig. Sec. 1653D with 1653E.
Fig. 907.—Replace Sig. Sec. 1654D with 1654E.
Fig. 907–A.—Replace Sig. Sec. 1686D with 1686E.
Fig. 907–B.—Replace Sig. Sec. 1688B with 1688C.
Fig. 908.—Replace Sig. Sec. 1640B with 1640C.
Fig. 909.—Replace Sig. Sec. 1642C with 1642D.
Fig. 910.—Replace Sig. Sec. 1643C with 1643D.
Fig. 911.—Replace Sig. Sec. 1644B with 1644C.
Fig. 912.—Replace Sig. Sec. 1645B with 1645C.
Fig. 913.—Replace Sig. Sec. 1650B with 1650C.
Fig. 914.—Replace Sig. Sec. 1648B with 1648C.
Fig. 915.—Replace Sig. Sec. 1646B with 1646C.
Fig. 931–A.—Replace Sig. Sec. 1489B with 1489C.

Report of Committee 14—Yards and Terminals

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Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, including recommended revisions or readoption of those portions of the Manual in which no changes or revisions have been made subsequent to 1936 ..... page 96

2. Classification yards, collaborating with Committee 16.
   Progress report, submitted as information ..... page 100

3. Scales used in railway service.
   No report.

4. Bibliography on subjects pertaining to yards and terminals appearing in recent publications.
   Progress report, presented as information ..... page 103

5. Locomotive terminal facilities.
   Progress report on terminal facilities for diesel electric locomotives, presented as information ..... page 110

6. Facilities for expediting freight traffic through yards and terminals.
   No report.

7. Communication systems in yards and terminals.
   No report.

8. Facilities for mechanical handling of l.c.l. freight at freight houses, collaborating with Committee 6.
   Progress report on conveyor handling of l.c.l. freight ..... page 113

The Committee on Yards and Terminals,
G. F. Hand, *Chairman.*

AREA Bulletin 469, November 1947.

Report on Assignment 1

Revision of Manual

L. L. Lyford (chairman, subcommittee), J. E. Armstrong, H. Austill, M. H. Dick, H. C. Forman, W. H. Giles, G. F. Hand, M. J. J. Harrison, E. M. Hastings, W. J. Hedley, W. H. Hobbs, J. E. Hoving, C. E. Merriman, C. H. Mottier, E. E. R. Tratman.

The committee has reviewed those portions of the Manual in which no changes or revisions have been made subsequent to 1936, and recommends the following action:

I TERMINALS

Delete sections 11 and 12, pages 14–1 and 14–2, and insert in their places the following:

11. General

(a) This chapter deals with the engineering and economic problems of location, design and construction of a terminal. It contemplates the establishment of entirely new facilities, but is also applicable to existing facilities which are to be rearranged, modernized, enlarged or consolidated.

(b) A terminal may be provided and maintained either by an individual railway or jointly in behalf of two or more railways.

(c) The engineering problems involved in the location, design and construction of a terminal are substantially the same whether the ownership and use is to be individual or joint. In either case, the location and arrangement of the terminal as a whole should permit the most convenient and economical access to it of the tributary lines of railway, and the location, design and capacity of the several facilities within the terminal should be such as to handle the tributary traffic expeditiously and economically, and serve the public conveniently.

(d) In the design of a new terminal, preservation of existing railway routes and facilities, while seemingly desirable from the standpoint of initial expense, may be extravagant from the standpoint of operating costs and efficiency. A true economic balance should be achieved, keeping in mind possible future changes in traffic, as to volume, periodic intensity, direction and character.

12. Joint Terminals

(a) It is not axiomatic that a joint terminal under one management can be operated more economically and satisfactorily than two or more separately operated terminals of the same aggregate capacity.

(b) A joint terminal should not be undertaken without exhaustive comparable analyses of what may be attained in expedition, economy and convenience, under the arrangements to be surrendered and under those proposed.

(c) A joint terminal may be undertaken where analyses justify anticipation of its economy as compared with other available alternatives, or where governmental authority or popular demand has substantially the force of mandate.

(d) In a joint terminal, a single organization should control all construction, operation, maintenance and other activities within the terminal zone. All employees, including those of the participating railways, while functioning within the terminal zone should be subject to the control of the appropriate terminal officers.

(a) A joint terminal agreement should anticipate and definitely cover all relationships between and among the owners, the users and the management of the joint ter-

minal company. With a view to discovering weaknesses and omissions which may be overcome in a new agreement, it will be found helpful, before drafting it, to examine existing agreements and consult those charged with their administration.

Note.—See Chapter 20 of this Manual:
Form of Agreement for Joint Use of Passenger Station Facilities.
Form of Agreement for Joint Use of Freight Terminal Facilities.
Form of Agreement for the Organization and Operation of a Joint Passenger Terminal Propect.
See AREA Proceedings, Vol. 37, 1936, page 309, for chart showing Typical Terminal Organization.

Delete the chart entitled, "TYPICAL OUTLINE FOR MAXIMUM ORGANIZATION FOR TERMINAL CONTROL," on page 14–3.

II PASSENGER TERMINALS

Readopt all paragraphs of section 21, pages 14–4 and 14–5, except the following:

Delete the words "Pullman sleepers and private cars" in line 8 (b) paragraph (i) and insert in their place the words "sleeping, private and business cars."

Readopt all paragraphs of section 22, pages 14–5 and 14–6, except as follows:

Delete the words "provided" and "at any time" in the first line of paragraph (a) and insert the word "such" in place of "provided." Delete the word "approaches" in the first line of paragraph (j) and insert the words "approach tracks," in its place. Insert the word "train" between the words "passenger" and "traffic" in the last line of paragraph (j).

Readopt all paragraphs of section 23, page 14–6.

Readopt paragraphs (a) and (a) 1 under section 2401, page 14–6.

Insert the words "fixed or moving" between the words "as" and "stairways" in the second line of paragraph (a) 2, page 14–6.

Delete the words "having to be provided by the railway company" in paragraphs (a) 3, (a) 4 and (a) 5, page 14–7; also delete the word "vehicles" after the word "public" in line 2, paragraph (a) 5.

Readopt all paragraphs of section 2402, page 14–7, except (a), (c) and (d) which should be revised to read as follows:

(a) The principal floor areas should include a lobby, waiting room or rooms and a passenger concourse or any combination of these facilities, and separate men's and women's retiring rooms.

(c) The lobby should front upon the principal public entrances and exits, and it, solely or together with the passenger concourse, should be the business area of the station. The principal station facilities, such as information booths, ticket office, baggage check counter, parcel check room, telephone and telegraph facilities, parcel checking lockers, etc., should be located in proper sequence along the line of travel and clearly indicated to avoid confusion and to reduce the walking distance of passengers to a minimum.

(d) An adequate and conspicuous train bulletin board should be provided. A public announcing system may be desirable.

Readopt all paragraphs of section 2403, pages 14–7 and 14–8.

Readopt paragraphs (a) and (c) of section 2404, page 14–8, and revise paragraph (b) to read as follows:

(b) Windows or counters along the passenger concourse for the sale of local tickets are desirable.

Revise the title of section 2405, page 14–8, to read as follows:

2405. Parcel Rooms and Parcel Checking Lockers

Add the following to the existing Manual material: "Self service parcel checking lockers should be placed at convenient locations."

Revise section 2406, page 14–8, to read as follows:

2406. Toilet and Washroom Facilities

Pay toilets and pay washroom facilities should be provided. However, there should be an adequate number of free toilets and lavatories.

Readopt sections 2407 and 2408, pages 14–8 and 14–9.

Revise section 2409, page 14–9, to read as follows:

2409. Facilities for Public and Private Vehicles

The extent of such facilities depends on the size of the city, character of service, and other means of local transportation. In cities where good taxicab service is available at a reasonable rate, a large percentage of passengers use that service as a means of reaching and leaving the station.

Adequate parking space convenient to the station for railroad patrons is desirable. In some places, pay parking facilities for private automobiles have been provided for the accommodation of patrons.

Readopt all paragraphs of section 2410, pages 14–9, 14–10 and 14–11, except as follows:

Delete the word "maximal" and insert the word "maximum" in line 4, paragraph (a).

Delete the word "escalator" and insert the words "fixed or moving" before "stairways," in line 3, paragraph (b) 1.

Delete the word "minimal" and insert the word "minimum" in line 1, paragraph (b) 4 (f).

Delete the word "maximal" and insert the word "maximum" in lines 4 and 7 paragraph (b) 4 (i).

Readopt section 2411, except delete the words "or escalators" in paragraph (e).

Readopt sections 2412, 2413 and 2414, pages 14–11 and 14–12.

Readopt paragraphs (b) and (c) section 2415 and eliminate the words "occupy less space" in lines one and two of paragraph (a). Delete the word "minimal" and insert the word "minimum" in line 1, paragraph (a).

Readopt all paragraphs of section 2416, page 14–12.

Readopt Table 1401, page 14–13.

Readopt all paragraphs of section 2417, pages 14–14 and 14–15, except delete the word "Pullman" in sentence (a) 1 (a) and insert the words "sleeping cars."

Readopt Fig. 1401 and section 2418, page 14–15.

Readopt Fig. 1402, page 14–16.

Readopt section 2419, page 14–17, except delete the word "and" in the first sentence and insert the words "and audible intercommunication systems" between the words "tubes" 'and "may" in the first sentence.

Readopt section 2420, page 14–17.

Revise the title of section 2421 to read as follows:

2421. Steam, Air and Water Connections

Add the following to the existing Manual material: "At stations where equipment may be watered, hydrants spaced two car lengths apart (preferably serving two tracks) should be provided."

III FREIGHT TERMINALS

Readopt all paragraphs of section 31, pages 14–18.2 and 14–19, except (e), (f) and (g) which should be revised to read as follows:

(e) Each part of the complete assembly must be so located with relation to the whole that, so far as physically possible, all movements through the terminal shall be straightforward, through shortest routes, unhindered by cross or counter movements. Proper allowance should be made for future expansion.

(f) Terminal delays constitute a very serious handicap to the expeditious movements of freight and a material decrease in such delays will justify a large investment.

(g) In any case where relief is sought because an existing terminal imposes excessive delays, a thorough study should be made to determine the advisability of providing a layout wholly new and correct in design, before attempting to remodel the existing facilities.

Readopt all paragraphs of section 32, pages 14–19 and 14–20, except as follows:

Delete paragraph (e) and insert the following in its place:

(e) The type of classification yard which should be adopted in any given case depends upon the volume and character of traffic to be handled through it, and the train schedules.

Change paragraph (i) to (j) and insert a new paragraph (i) reading as follows:

(i) An adequate drainage system will assist materially in keeping maintenance costs to a minimum and improve operations.

Readopt all paragraphs of section 321, pages 14–20 and 14–21, except paragraph (i) and add to paragraphs (f) and (g) the following::

"State requirements must be observed."

Insert the words "not less than" after the word "capacity" in the first line of paragraph (i).

Readopt all paragraphs of section 322, page 14–21, execpt as follows:

Delete paragraph (a) and insert in its place the following:

*(a) When the volume of traffic or other conditions justify a hump yard to meet the requirements, the yard should be designed for a continuous movement over the hump and for movement of cars by gravity from the hump to their proper tracks in the classification yard without damaging impacts, and for a minimum loss of time between successive humping operations.

In paragraph (c) insert between the words "should" and "be" the word "generally," change the word "maximal"' to "maximum," and add the following sentence: "The type and power of the locomotive should also be considered."

Delete paragraph (d) and insert the following:

(d) The receiving tracks should be placed as close as possible to the hump after necessary space is allowed between the receiving tracks and the hump for the release of locomotives on incoming trains, for the placing of turnout to permit car movements around the hump, and other facilities, such as oiler for car wheel journals, that may be desired at this location. A second track leading from the receiving yard to the hump will permit the use of a second hump locomotive for continuous humping operations.

* References, Vol. 30, 1929, p. 762; Vol. 31, 1930, p. 1014; and Vol. 32, 1931, p. 963.

If trains from each direction are to be humped in one direction over the hump, provisions should be made so that cars can be moved into the end of the receiving yard next to the hump without stopping humping operations.

Add the following references at the bottom of the page:

Readopt paragraphs (a) and (c) of section 323, pages 14–21 and 14–22.

Delete paragraphs (b) and (d) page 14–22, and insert in their places the following:

(b) The gradient from the summit of the hump should be such that cars under usual weather and temperature conditions will run by gravity to the far end of each classification track and under severe weather and temperature conditions will run by gravity several hundred feet beyond the clearance point of each track. Steep grades should be provided below the hump so that cars will quickly separate, thereby permitting the lineup of switches for each car or cut of cars without slowing up humping operations. A stretch of level track at the leaving end of classification yard, with a slight ascending gradient to ladders at this end of the yard, is desirable.

(d) Install gradient suitable for empty car movements on classification tracks to be used for that purpose.

Readopt all paragraphs of sections 324 and 325, pages 14–22 and 14–23.

Readopt paragraphs (a) and (b) of section 331, page 14–23. Revise paragraph (c) to read as follows:

(c) It is desirable that the gradient of the receiving tracks be such that hand brakes will not have to be set to keep the cars from moving.

Insert new paragraph (d) reading as follows:

(d) Consideration may be given to track indicators and remotely controlled switches at entrance to the receiving yard.

Readopt all paragraphs of sections 332, 333, 334 and 335, pages 14–23, 14–24 and 14–24–1.

Defer action on section 34, pages 14–25, 14–26 and 14–27.

Readopt all paragraphs of sections 371, 372, 373, 374 and 375, pages 14–31 and 14–32.

Report on Assignment 2

Classification Yards, Collaborating with Committee 16—Economics of Railway Location and Operation

H. C. Forman (chairman, subcommittee), J. E. Armstrong, C. J. Astrue, F. E. Austerman, N. C. L. Brown, H. F. Burch, F. W. Creedle, W. H. Giles, A. J. Greenough, G. F. Hand, M. J. J. Harrison, H. H. Harsh, D. C. Hastings, E. M. Hastings, F. M. Hawthorne, F. A. Hess, J. L. Loida, C. E. Merriman, C. H. Mottier, W. B. Rudd, S. H. Shepley, J. N. Todd, V. R. Walling, J. B. Whiting, R. W. Willis.

This report is submitted as information. This year your committee has selected under its general assignment the subject of Methods of Marking Switches. Information has been gathered from 23 different railroads and the report describes and illustrates various methods of identifying switches. Individual cases and locations show quite different methods due to the number of combinations of variable factors. It is impracticable to establish a standard that would be applicable to all situations.

The information obtained indicates that on a large percentage of the roads some method of identifying switches in yards has been attempted by the switchmen and local officers. It indicates a definite necessity and trend toward a permanent, satisfactory method of numbering switches. It is the opinion of your committee that industry tracks, spur tracks and line of road tracks, which are not a part of a yard, need not be marked with numbers. However, operating tracks (receiving, classification, repair, etc.) and storage tracks in yards and terminals should be identified by numbering.

For the purpose of illustration it is assumed that each road will design fastenings to suit the particular stand used, if needed. It may be necessary to use two or more systems of numbering switches on one road. So far as practicable each road should adopt the one method best suited to its particular conditions.

Typical methods of numbering switches are described below, and illustrated by Figs. 1 to 6, incl.

Fig. 1

General Description.—A metal plate of sheet iron bent so that the base is at right angles to the face on which the numbers are to be placed. The base of this plate is drilled and bolted to the switch stand by one of the bolts holding the upper housing to the stand.

Numerals are 3½ in. Egyptian style, black on a white background or reflector plates of numbers bolted to the metal plate.

Remarks:

1. It can be readily seen, even during the winter months when there may be an accumulation of snow on the ground.
2. The location on the stand is such that it will not be easily damaged or destroyed.
2. It is easily cleaned or painted.

Fig. 2

General Description.—Numerals are painted or stenciled directly on the switch target or vanes in a contrasting color, or reflector plates of numbers may be bolted to the target. Size and type of numerals will depend upon the size and type of target used.

Remarks:

1. It can be easily seen and will not be covered by snow.
2. It can be easily painted or cleaned.

This type of identification will have to be repainted each time the targets are painted. The numbers, due to the colored background, will not be as easy to read as those shown in Fig. 1.

Fig. 3

General Description.—Numerals are painted or stenciled on the disk of the lamp, in contrasting colors.

Remarks.—While they are not likely to be covered by snow, the numbers are not large enough, and cannot be easily read, due to the colored background.

Fig. 4

General Description.—The metal plate is bent so that the base is at right angles to the face on which the numbers are to be placed, and the plate fastened to the headblock ties.

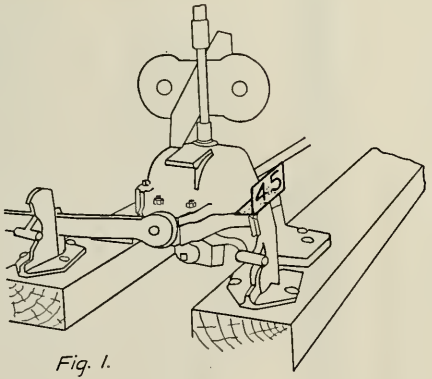

Fig. 1.

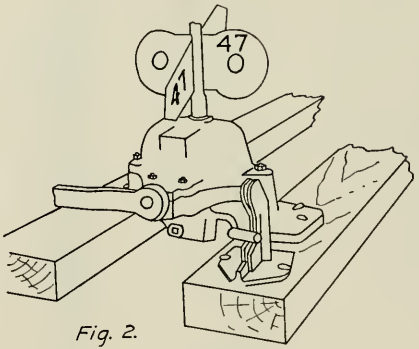

Fig. 2.

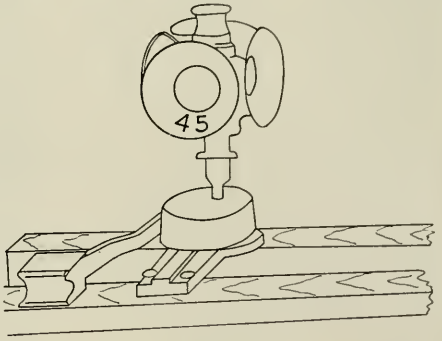

Fig. 3.

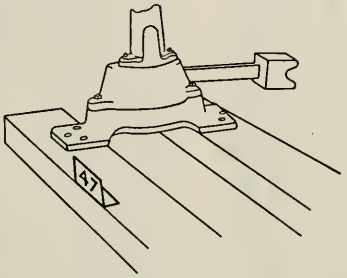

Fig. 4.

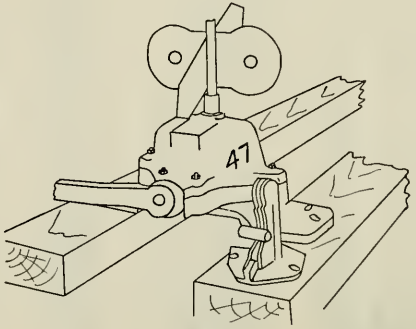

Fig. 5.

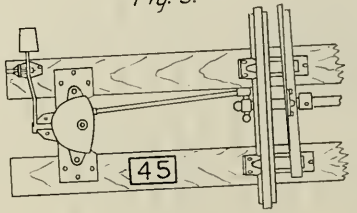

Fig. 6.

Typical Methods of Numbering Switches.

Numerals may be stenciled or painted in black on a white background. Reflector plates will require frequqent cleaning and replacements. Numerals may be made by drilling holes in the plate. This would require practically no maintenance.

Remarks.—It would be covered by a light snow, splattered with dirt by a rain, and hard to maintain in a condition so that it could be easily read. If not placed carefully it would also be a safety hazard, especially with an accumulation of snow.

Fig. 5

General Description.—The number is painted directly on the bowl of the switch stand.

Remarks.—It would be covered by snow piling upon the stand, and would require frequent painting, which would be difficult because of the greasc that usually accumulates on this portion of stands in yards.

Fig. 6

General Description.—In using this type of switch identification the number is placed directly on the switch headblock ties in a horizontal position, in one of the following methods:

1. Painted directly on the top of the tie.
2. Painted or stenciled on a metal plate with the plate fastened to the top of the tie.

Remarks.—This type of switch identification is easily applied but soon would be obliterated by dirt, grease or snow, and would have to be repainted several times a year. When observed from a distance the angle is so acute it is difficult to read.

Summary

1. Many roads have found it advantageous to mark switches in yards with numbers.
2. The numbers should be clear and easily read at a glance. Where much night switching is done serious consideration should be given to reflector type numerals.
3. Each road should adopt the method best suited to its particular conditions.
4. Various methods in use are illustrated in Figs. 1 to 6, incl.

Report on Assignment 4

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E. E. R. Tratman (chairman, subcommittee), F. T. Darrow, M. H. Dick, G. F. Hand, F. A. Hess, J. E. Hoving.

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to convert the competitive systems into one government transport system (railways and roads), with consequent revision of routes and probable relocation of many yards and terminals.

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Report on Assignment 5

Locomotive Terminal Facilities

Diesel Electric Locomotives

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Your committee submits the following report as information.

General

Diesel locomotives are being added to the locomotive fleets in increasing numbers. The diesels used in road service are usually of one to four units and are of such length that existing terminal facilities for steam locomotives are inadequate. Furthermore, the type of construction of the diesel locomotives requires that special facilities be provided for servicing them at terminals. Diesel terminal shops can be incorporated with steam locomotive facilities by remodeling or reconstructing existing structures. New facilities can be provided adjacent to or remote from existing steam locomotive terminals, depending upon local conditions. It may be found advantageous to utilize existing facilities and forces to the fullest extent as economies may result from incorporating diesel and steam locomotive facilities in the same terminal. Where existing steam locomotive shop facilities are to be remodeled or reconstructed to provide facilities for the diesel locomotives also, the two areas should be separated by a fire wall.

Location and General Layout

Location.—If a new location for a terminal is decided upon, it should be such that the movements of the locomotive to and from its train are held to a minimum. A study of the requirements of the new facility should be made so that adequate provisions can be made for handling the locomotives.

Site.—In deciding on the site, consideration must be given to land values, preparation of the site, type of foundation, drainage, sewers, water supply, electricity, labor supply, fire protection, future expansion of the terminal and the relation to existing yard and terminal facilities.

Track layout.—The track layout should be such as to provide orderly movement of locomotives to and from the shops and terminals, and there should be at least one run-around track to bypass the shop.

Diesel Shop Building—Facilities for Running and Heavy Repairs

Size of Building.—The size of the building is determined by the length of units and the number to be housed simultaneously. Generally, a rectangular structure will be found to best serve the requirements. The structure as a rule should be so designed that facilities will be provided for running repairs, heavy repairs, machine shop, parts cleaning and parts conditioning, wheel supply and storage, lockers, washroom, toilet and office.

Construction.—The construction employed should be fire resistant. Large panels of glass block windows with center pivoted window sash are coming into increasing use.

Tracks.—The number and length of tracks should be sufficient to accommodate the locomotives to be housed at any one time. All running repair tracks preferably should be through tracks, while the tracks for heavy repairs can be stub ended. The desirable

distance between track centers is not less than 23 ft., which will allow for a 12-ft. width of working platform.

Heating.—Heating can be accomplished by means of a central heating plant or a separate plant for the particular building. At terminals a central heating plant can usually be utilized to advantage.

Lighting.—The building should be designed to give a maximum amount of daylight to the interior. Fluorescent, incandescent, or mercury lamps should be provided throughout the shop building, employing fluorescent lighting where greater intensity of light is required. The locomotive pits should have lights within the pit section and illumination provided both below and above the elevated platforms. Outlets for lighting extensions and power tools should be provided at frequent intervals.

Fire protection.—Fire protection facilities should be provided and so arranged as to permit complete coverage of the shop structure. These facilities should consist of fire hydrants and hose lines, with nozzles of the fine-spray type for oil fires. Air-foam equipment and approved fire extinguishers should be located at various strategic points.

Ventilating of Exhaust Gases.—Effective ventilation within the shop can be provided by means of roof ventilators aided by a section of ventilating sash in the wall sections. On any of the tracks where the locomotive will be run for testing and maintenance, overhead exhaust hoods long enough to collect the exhaust gases from multiple units should be placed just a few inches above the exhaust outlets. The hoods should be connected to an exhaust duct system equipped with a fan for expelling the gases through the roof. If the volume of exhaust gases is not too great roof ventilators can be relied upon to dissipate the exhaust fumes; however, it may be necessary to provide power driven fans in the ventilators.

Engine Pits.—All diesel servicing tracks within the shop should have engine pits for inspection and repair purposes. Pits 4 ft. wide and 4 ft. 6 in. deep from the top of rail will be found satisfactory. Ledges half way up the pits for supporting planks for men working on the underframes may be of advantage.

The engine pits may be of concrete construction with the floor of the pit pitched for drainage. Ramps or stairs should be provided to permit easy entrance to the pits. A wall-less pit, with the running rails supported on short columns, is sometimes found desirable.

The pits should be of adequate length to accommodate the longest assembly of diesel locomotive units.

The elevation of the shop floor between the pit tracks is usually established at 30 in. below the top of the pit rails to allow shop men to work on the sides of the locomotive mechanism, running gear and brake rigging without unnecessary stooping.

Where required, facilities should be provided in the pits for the melting of snow and ice on the running gear of the locomotives. These facilities may be of a type which is built into the pits or of a portable type. The pits should be connected with the sewer system so that proper drainage is provided.

Jacking Pads.—In heavy repair shops where screw or hydraulic locomotive jacks will be used to raise the body of the diesel locomotive, jacking pads should be incorporated along the sides of the pit walls. These pads should be so located that they will be in the proper position for all types of locomotives to be repaired.

Drop Table.—A drop table which will permit the replacing of a complete truck or a single pair of wheels with their traction motor should be provided and so arranged as to permit moving the trucks or wheels to and from the machine shop or truck storage track.

Elevated Platforms Between Pits.—To permit repair work alongside the tracks in the shop, elevated platforms are provided with the surface of the platform at the ap-

proximate elevation of the floor of the locomotive body. A clearance of 5 ft. 6 in. from center line of the track to the edge of the platform and a height of the platform floor above the top of pit rail of 4 ft. 10 in. will provide good working space. Some diesel locomotives have removable hatches for access to motor heads. Repair work at this level is facilitated by providing a second tier of high platforms at locomotive roof level.

The elevated platforms should be constructed of fire resisting material. Each of the running repair tracks in the shop should be provided with an elevated platform. The platforms should be of such length as to accommodate the longest of the diesel locomotives. The desirable minimum width of a platform serving two tracks is 12 ft. As a safety measure the platforms should be equipped with removable railings.

Overhead Traveling Cranes.—To permit the handling of engines, generators and heavy parts, overhead traveling cranes are provided to carry parts to and from the areas set aside for repair purposes. Under clearance below the crane bridge should be sufficient to handle the parts to the desired location. A 25-ton crane with a 5-ton auxiliary hoist has proved ample in most cases; however, a 30-ton crane has been found desirable in some later installations. Smaller cranes of from 2 to 5 tons capacity have been found ample for running repair shops.

Machine Shop.—The machine shop in which is placed the necessary tools and machines for making the required repairs to the diesel engine units should be located adjacent to the repair shop. Hoists, ranging from ½ ton to 1½ tons capacity, will facilitate the operation in the shops.

Wheel Supply and Storage.—Wheel supply and storage facilities adjacent to the repair shop should be provided to assure a convenient supply of wheels for repair purposes. Facilities should be provided to store pairs of wheels with their traction motors attached.

Parts Conditioning and Cleaning.—A room equipped with benches, tools, rack and trays for necessary reconditioning of the various parts should be provided convenient to the machine shop and adjacent to a room equipped with tanks, rinsing trays, drying trays, and racks for cleaning of parts.

Lubricating Oil Facilities.—The tanks for new oil should be of sufficient size to handle oil in carload lots. Tanks will be required for new oil (usually two), worn and dirty oil and reclaimed oil.

Pumps of the desired size and capacity equipped with bypasses and explosion proof motors with remote or pressure operated switches should be provided for handling the oil.

The lubricating oil facilities may be housed in the repair shop proper or in a separate structure. Fire resistant construction should be employed. Meters should be provided to accurately measure lubricating oil delivered to the units. Facilities may be provided for reclaiming worn and dirty lubricating oil.

A lubricating oil piping system should be installed so that outlets are available at the engine room door locations, either above or below the elevated platform level in the running repair shop. A drain line should also be installed from these locations to the dirty oil tanks for convenient draining of the locomotive crank cases.

Water.—Where satisfactory water is not available, adequately treated water must be provided for the cooling system and steam generation.

Locker, Wash and Toilet room.—Locker, wash and toilet room facilities for the employees should be installed adjacent to the repair shop areas.

Fuel Oil Facilities

Servicing.—Oil fueling facilities should be located on the lead to the shop and consist of oil storage tanks and enough oil delivery columns to permit fueling of all units

of the locomotive with one spotting. To keep an accurate inventory of the oil received, disbursed and on hand, meters should be provided for all the operations. Strainers in the line from the tank car delivery point to the storage tanks and filters in the delivery line to the locomotive are a necessity to prevent foreign matter entering the locomotive fuel tanks.

Storage.—Tanks either above ground or buried, depending upon local regulations, should have enough capacity to insure an ample reserve supply of fuel oil. If above ground, the tanks should be diked by a concrete or dirt wall. The tanks should be provided with air vents and water drains. Manhole openings in the top of the tank should be provided to permit cleaning.

Pumps.—Motor-driven pump or pumps, housed in a pump house, are required for handling oil into storage and to the servicing outlets.

Sanding Facilities

Sanding facilities should be located on the shop lead adjacent to the fuel delivery racks. Sanding facilities consist of a storage bin for wet sand, a sand dryer, dry sand overhead hoppers and spouts from the overhead hoppers to reach the sand boxes on the locomotives. Existing sanding facilities for steam locomotives may be readily converted to handle diesel locomotives.

Locomotive Washing Facilties

A locomotive washing facility located on the shop lead track and so situated that the locomotives are washed as they leave the fueling platform will be found desirable. Brushes and spray pipes can be so arranged that the operation is automatic when the locomotive shunts the track rails at the washer. Some hand washing of the locomotive may be found necessary. A washing platform with or without a pit to facilitate cleaning the underside of the locomotives may be found desirable.

Store Room for Diesel Parts

Facilities for storing parts for the diesel locomotives should be provided at the terminal in close proximity to the diesel shop. If there is an existing store room serving the terminal it may be found that there is adequate space to accommodate the additional parts and if not an addition to the store room should be constructed.

Report on Assignment 8

Facilities for Mechanical Handling of L.C.L. Freight at Freight Houses Collaborating with Committee 6—Buildings

W. O. Boessneck (chairman, subcommittee), C. J. Astrue, M. H. Dick, A. J. Greenough, G. F. Hand, F. M. Hawthorne, W. H. Hobbs, E. C. Jackson, J. S. Knight, C. A. Mitchell, C. H. Mottier, H. M. Roeser, J. N. Todd, E. E. R. Tratman, R. W. Willis.

Your committee submits the following initial progress report as information in respect to conveyor handling. It is intended that the subject be continued with respect to other mechanical means for handling l.c.l. freight at freight houses.

To date, no installation has been reported where conveyor handling on a large scale has been placed in service in the United States for the transfer of l.c.l. freight. At this time, however, it would seem appropriate to give an outline description of installations

in the United States which have been handling express transfer successfully for several years and of one in England which is used for l.c.l. freight.

Overhead Chain Conveyor

Basically the large express conveyors, at their present stage of development, consist of suitably smooth and durable floors, for the support of a continuous procession of rubber-tired trailers weighing perhaps a ton each loaded and propelled by a standard trolley conveyor mechanism as used in many factories. The latter is continuous and consists of an overhead rigid track, usually a 4-in. I-beam, carrying ball bearing trolley wheel-and-hanger assemblies spaced 24 in. or as required, and tied together below the I-beam track by a rivetless chain made of drop forged links and interlocking pins. This chain serves to transmit the driving force, which is provided usually by 20-hp. fixed electric power units placed where dictated by the needs of the particular layout. In most factory installations, these trolley wheel hangers carry the loads in slings or baskets, but in the type which is covered in this report, double hangers carry vertical drive pins which fit into vertically movable sockets in each individual trailer. By this means, the trailers are instantly attachable to, or detachable from, the chain at the proper spacing, which gives at least 2-ft. clearance between adjacent trailers. The trailers are all-metal 3-deck carriages 10 ft. long and 3 ft. wide having swiveled front wheels and fixed-axle rear wheels. Each deck has movable partitions fabricated of pipe to facilitate separation of the loads.

The length of circuit possible in such a mechanism is practically unlimited. One installation in daily use, known as the West Side Terminal located at 10th Avenue and West 32nd street, New York City, has a length of 2520 ft., with almost 600 deg. total curvature (the sharpest curve being of 16-ft. radius) and three 20-hp. driving units. Another installation located at Jacksonville, Fla., is normally operated as two systems, but can be readily coupled to form one line 3642 ft. long and handling 496 trailers with its three 20-hp. driving units. Still another installation is located in the Jackson Heights section of New York City.

The usual speed of the newer conveyors is 125 ft. per min. (approximately 1½ mph.). The theoretical capacity of the 2520-ft. West Side Terminal layout is given as 18,500 pieces or 250 tons per hour, using 187 trailers in groups of three with working spaces between groups.

Variations in floor level are readily accommodated, the above mentioned 2520-ft. West Side Terminal layout having 15 percent grades to a conveyor bridge over an entrance track which has a span on a 19-ft. horizontal radius for reversal of direction. Dog type safety stops prevent trailers from backing down grade in case of chain breakage; ball governors prevent overspeed of loads descending in the normal direction.

Push button stop-start controls may be provided at any number of convenient locations, with bell or horn warnings to announce a start all around the circuit.

The electrical drive, and the number and size of units, depend upon the length of the chain circuit, and the loads, gradients and speed, and must be arranged to prevent excessive stress in the chain.

As the packages of outbound merchandise come from the street vehicles, employees known as assorters place the shipments in the designated bins of the trailers. As the trailers pass by the railway cars, a platform employee or picker, at each car door removes the shipments that are for his car from the trailer bins. Car loaders then arrange the shipments within the car.

On inbound movement the assorters are stationed at the car sides and place the shipments in the trailer bins corresponding to the routes, and pickers at the tailboard side of the main platform remove the shipments for their particular routes.

If a package is missed on its first trip around it merely rides the circuit and is removed the next time.

The loading and unloading the trailers are facilitated by the provision of lightweight portable roller conveyors; both gravity and hand-push operation are used. The units are 10 or 13 ft. long and are framed in magnesium alloy to keep the weight within practicable bounds. These can be spotted in car doors and run into motor trucks. The rollers are ball bearing, 1⅞ in. diameter and 18 in. long.

Sorting and classification compartments on each trailer are stenciled with the names of schedules, destination points as required for outbound business, and local routes for the inbound movement. In at least one successful installation of this type, the wordings are given further emphasis by a color code to distinguish between classifications of trailers. Lot shipments to a common destination whose bulk exceeds the space assigned that destination in any one trailer are loaded onto a standard 3-ft. by 8-ft. platform truck and coupled to the rear trailer of a group on the chain, thus avoiding breaking up the shipment. This might well be a standard procedure in the handling of outsize l.c.l. loads, and greater spaces between groups of trailers to accommodate larger platform trucks could readily be provided.

It is important that adequate illumination be furnished at all points along the conveyor where transfers may be made. Large fluorescent reflecting fixtures have proved satisfactory for this purpose.

The building housing the 2520-ft. West Side Terminal layout contains five stub tracks, two island platforms 16 ft. wide and one main trucking platform about 75 ft. wide, and measures 200 ft. by 700 ft. so is not unlike the usual l.c.l. facilities.

Mechanized Freight Station at Birmingham, England

In Birmingham, England the London, Midland & Scottish Railway has a mechanized freight station 350 ft. by 650 ft. Its north side handles inbound freight and the south side, outbound. Fig. 1 is a general plan of this installation.

Outbound, there are eight stub tracks (six in pairs) with a capacity of 200 short cars, and served by four driveways. Just outside the building is a transfer table runway for the lateral shifting of cars. Cars are moved by electric capstans. Grade crossings provide highway access to the driveways alongside the cars.

Motor trucks and wagons bringing in freight are driven alongside the cars placed for loading. The parcels are handled by two-ton electric cranes mounted on pneumatic tires and having horizontal booms that can be run into the cars to deposit the loads. When a truck brings in a miscellaneous load for various destinations, it is unloaded at a special sorting platform or deck at the west end of the shed. Here the goods are sorted and loaded on rubber-tired "drays" (like station baggage trucks) which are hauled by horses or tractors to the proper cars.

Inbound, alongside the cars are two wood slat-on-chains conveyors similar to the pallet or apron conveyors used alongside cars in some of our industrial plants. There are two pairs of stub tracks about 200 ft. long (for 10 cars each). Just outside the building, each track splits into two yard tracks for loaded and unloaded 10-car "rafts." The conveyors, between the two tracks of each pair, are 360 ft. long, thus extending 160 ft. beyond the track ends. The speed of the conveyors is said to be 40 ft. per min., using a 15-hp. motor. Along one side of tht 160 ft. length of the conveyor, highway trucks and small transfer trucks are backed up; along the other side are traveling "flats" 6½ ft. by 14 ft. riding on two 3-ft. gage tracks. Each flat carries an average of 500 to 600 lb. Any one flat may have to deliver its load to any of 48 tail-board spaces. The flats on each of the two parallel tracks are moved by gripping a chain traveling at 500 ft. per min.,

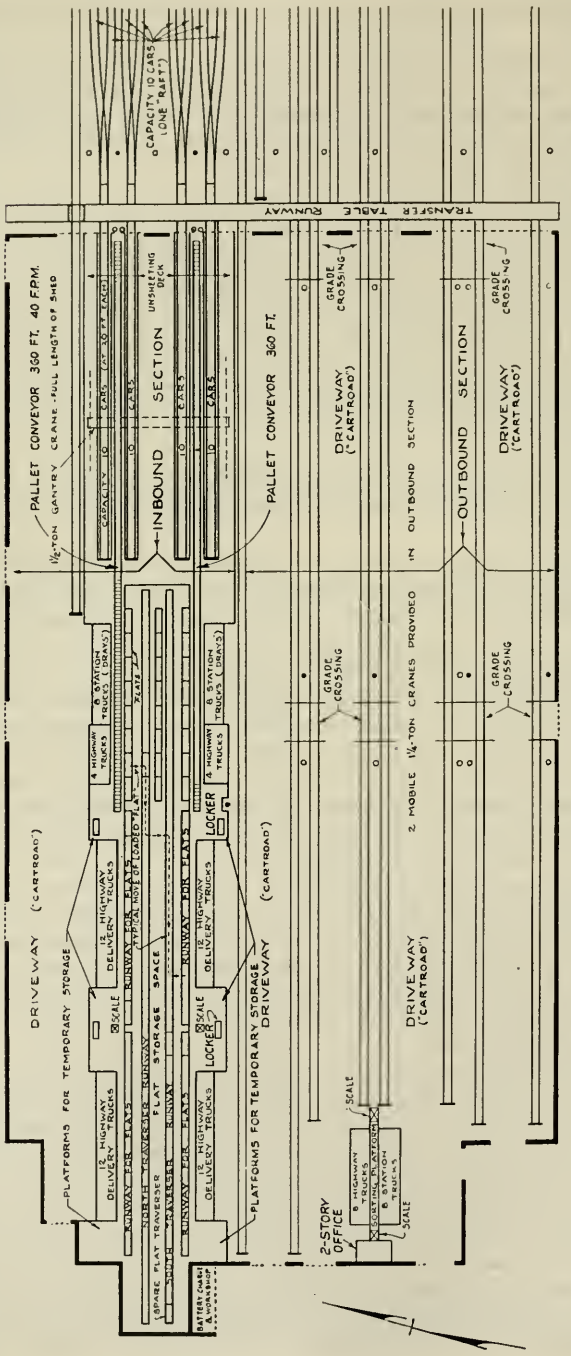

Fig. 1.—General Plan of Mechanized Freight Station at Birmingham, England.

driven by a 20-hp. motor. The gripping mechanism is actuated on each flat. To transfer flats from one track to the other, a cross-transfer carriage is provided which is thrust laterally under the flat to be transferred. This flat is then lifted, transferred and lowered to engage the other track and chain.

Goods from the inbound cars are placed on the conveyor, with labels uppermost. When a set or raft of ten cars is empty it is hauled away and a loaded raft is set in its place. Along that part of the conveyor which extends beyond the tracks are stationed sorters who pick off the packages. Should a package be missed it trips a hinged bar when it reaches the end of the conveyor, which stops the conveyor. The packages for forwarding by rail are put off on one side to a group of drays for delivery to appropriate cars on the outbound tracks. Packages for local distribution are put off on the opposite side to a row of flats. There are four discharge points for this local freight, each with tailboard space for 12 motor trucks, thus serving the 48 delivery and collection districts into which the city is divided.

Car Unloader Machines

The London, Midland & Scottish Railway also uses car unloading conveyors at Derby. These are fixed on platform at trackside and cars are spotted by a tractor having a projecting arm. An extensible boom carrying a belt conveyor is thrust into the car doorway to receive the packages which are delivered to an inclined roller conveyor. Packages are picked off the conveyor by sorters and placed onto station drays for delivery to cars on outbound tracks or to motor trucks or wagons for local distribution.

General

It is the opinion of the committee that generally it would be difficult to apply and to justify the conveyor of the type first described in this report, to the handling of l.c.l. shipments, for the following reasons:

1. A large amount of tonnage, consisting of large or heavy pieces at railway freight houses, cannot be handled by hand on or off a moving conveyor. To move this freight by such a conveyor requires the hooking on of four-wheel trucks while the conveyor is in motion and then removing the trucks under the same conditions.

2. Many pieces could not be handled at all by this method and require special handling by other means.

3. Considerable width of freight house would then be needed for the conveyor plus alleyways for handling these large or heavy pieces by hand truck or some other mechanical unit.

Conveyors are satisfactory for handling mail or other packages of a more or less uniform shape and size, but your committee considers that there are other mechanical devices such as tractor-trailer operation, fork trucks, palletizing, etc., which in general are more efficient and economical in handling l.c.l. freight.

Report of Committee 6—Buildings

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Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.

2. Preparation of specifications for railway buildings.
   Progress report, presented as information, consisting of Specifications for Timber Connectors in Railway Buildings and Specifications for Copper Tubing ..... page 120

3. Design of shop facilities for diesel locomotives.
   No report.

4. Servicing facilities for diesel locomotives.
   No report.

5. Fire retardant coatings, collaborating with Committee 17.
   No report.

6. Specifications for lumber for railway building purposes.
   No report.

7. Docks and wharves.
   No report.

8. Pile foundations for railway buildings.
   No report.

The Committee on Buildings,
H. C. Lorenz, *Chairman*.

AREA Bulletin 469, November 1947.

Report on Assignment 2

Preparation of Specifications for Railway Buildings

R. L. Fletcher (chairman, subcommittee), F. H. Alcott, C. M. Angel, G. A. Belden, C. E. Booth, E. Christiansen, H. M. Church, C. O. Coverley, A. H. Exon, B. M. Murdock, G. P. Nagtegaal, J. B. Schaub, E. W. Scripture, Jr., A. B. Stone, S. G. Urban, W. E. Webb, O. G. Wilbur.

Your committee submits the following tentative specifications for timber connectors and copper tubing as information and respectfully requests comments and criticisms thereon.

SPECIFICATIONS FOR TIMBER CONNECTORS IN RAILWAY BUILDINGS

Timber connectors should be of three general types as follows, or of such other types as approved by the engineer or architect: (1) Split rings, (2) toothed rings, and (3) shear plates.

Split rings shall be manufactured from hot rolled carbon steel conforming to the current ASTM Designation A 273. Each ring shall form a true closed circle with the principal axis of the cross section of the ring metal parallel to the geometric axis of the ring. The ring metal shall be bevelled from the central portion towards the edges to a thickness less than at midsection to insure a snug fit in a precut groove. The ring shall be cut through in one place in its circumference to form a tongue and slot. Split rings shall be placed in precut grooves or daps which shall have an inside diameter slightly larger than that of the ring and shall conform to the cross section of the ring. Grooves or daps shall be cut with tools accurately set and properly sharpened.

Toothed rings shall be stamped from hot rolled sheet steel conforming to the current ASTM Designation A 17, Type A, Grade I and shall be bent to form a circular corrugated sharp toothed band and welded into a solid ring.

Shear plates should be of two types (1) malleable iron or (2) pressed steel. The malleable iron shear plates shall be cast from malleable iron conforming to the current ASTM Designation A 47, Grade 35018 for Malleable Iron Castings. Each shear plate shall consist of a perforated round plate with a flange around the edge extending at right angles to the face of the plate, projecting from one face only. The plate portion shall have a central bolt hole with an integral hub concentric with the bolt hole and projecting from the same face as the flange. Pressed steel shear plates shall be manufactured from hot rolled carbon steel conforming to the current ASTM Designation A–273. Each plate shall be a true circle with a flange around the edge extending at right angles to the face of the plate and projecting from one face only. The plate shall have a central bolt hole and two small perforations on opposite sides of the hole and midway between the center and the outside circumference.

Both types of shear plates shall be placed in precut grooves or daps, which shall conform to the shape and size of the respective plates and these grooves or daps shall be cut with proper tools correctly sharpened and accurately set.

SPECIFICATIONS FOR COPPER TUBING

General

The contractor shall furnish all labor, materials, tools and equipment, except as may be otherwise noted, necessary to entirely complete the copper tubing installation covered by the specifications and as shown, called for or implied on the drawings.

Materials

Copper tubing shall be clean and free from cracks, seams, slivers, scale and other surface defects and shall conform to the current ASTM Designation B–88.

Solder used in making soldered joints or connections for hot water heating and plumbing shall be "50–50" tin-lead solder conforming to current ASTM Designation B–32 Alloy Grade 50A; and solder used for solder joints in tubing for other uses shall be of composition suitable for the installation for which it is to be used.

Fittings shall be cast bronze solder type, wrought copper solder type or cast bronze flared tube type fittings. Valves shall be cast bronze solder type or cast bronze flared tube type. Each fitting and valve shall have the size and the manufacturer's name cast or stamped in the metal. Cast bronze valves and fittings shall be of uniform quality, free from porosity cracks, shrinkage, defects, and the casting shall conform to current ASTM Designation B–61.

Use Classification

Underground or solidly enclosed lines shall be extra heavy class "K" annealed tubing. Fittings, joints and valves in underground installations shall be cast bronze flared tube type.

Tubing inside structures may be class "L" annealed or hard drawn copper tubing with cast bronze solder type valves and cast bronze or wrought copper solder type fittings.

Tubing for use in exposed work shall be in straight lengths while coiled tubing may be used in unexposed locations.

Workmanship

Tubing shall be installed in straight lengths as far as possible and where bends are necessary the radius of the bend shall be not less than six times the inside diameter of the tubing.

Tubing shall be cut square to length and burr removed. Contacting surfaces shall be thoroughly cleaned and all dark spots shall be removed. Soldered joints shall be made by heating the fitting with a torch to an even temperature so that solder will flow evenly but will not burn. All soldered joints shall be made using a noncorrosive flux.

Flared joints shall be made using approved flanging and sizing tools of the appropriate size. The use of wicking or other fillers will not be permitted in making flared joints.

Manufacturers Markings

On tubes $\frac{3}{8}$ in. in diameter and over, the trademark of the manufacturer and a mark indicative of type shall be permanently marked on each tube at intervals not greater than $1\frac{1}{2}$ ft.

All fittings shall be clearly marked with the manufacturers trademark and shall clearly indicate the size thereon.

Pipe Covering

Pipe covering shall be as specified in Section 1818 AREA Specifications for Plumbing.

General Conditions

All materials entering into the work and all methods used by the contractors shall be subject to the approval of the engineer, and no part of the work will be considered as finally accepted until all of the work is completed and accepted.

The general conditions as given in Section I of this specification shall be considered to apply with equal force to this section of the specification.

Report of Committee 20—Uniform General Contract Forms

W. R. Swatosh, *Chairman,*
E. H. Barnhart
H. F. Brockett
W. D. Faucette*
J. W. Hayes
C. J. Henry
W. D. Kirkpatrick
J. S. Lillie
J. E. Marsh
C. J. McCarty
A. A. Miller
W. L. Mogle
A. B. Montville
O. K. Morgan
F. L. Nicholson
C. B. Niehaus
W. G. Nusz
G. K. Davis, *Vice-Chairman,*
L. A. Olson
H. A. Palmer
G. W. Patterson
W. M. Post
Bruce Shaffner
B. M. Stephens
J. L. Way
Committee

* Died May 19, 1947.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, including recommended revisions ..... page 124

2. Form of construction contract for minor projects.
   Final report, submitted for adoption and printing in Manual ..... page 125

3. Form of agreement for construction of stop log or other structures for flood control.
   Final report, submitted for adoption and printing in Manual ..... page 130

4. Form of agreement to permit subsurface exploration by state or other government agencies, on railway right-of-way.
   Progress report, presented as information ..... page 133

The Committee on Uniform General Contract Forms,
W. R. Swatosh, *Chairman.*

William Dollison Faucette

William Dollison Faucette, executive representative of the Seaboard Air Line Railroad and a past-president of the Association, died on May 19, 1947. He was a member of the Committee on Uniform General Contract Forms from 1916 until his death. After service as subcommittee chairman, he was advanced to vice-chairman of the committee and later to chairman, which position he occupied from 1921 to 1926.

The Association, the railroad world, his friends and the community in which he lived have lost, in his passing, a cultured Christian gentleman, the like of whom helps to make the world a better place because of his having lived in it. He leaves behind him the respect and love of his many friends who feel deeply the great loss they have sustained.

Reference is made to the more comprehensive memoir appearing elsewhere in this volume.

AREA Bulletin 469, November 1947.

Report on Assignment 1

Revision of Manual

W. G. Nusz (chairman subcommittee), E. H. Barnhart, G. K. Davis, J. S. Lillie, A. A. Miller, A. B. Montville, O. K. Morgan, F. L. Nicholson, C. B. Niehaus, L. A. Olson, H. A. Palmer, G. W. Patterson, W. M. Post, W. R. Swatosh

The committee recommends reapproval of the Joint Passenger Terminal Agreement (Manual pages 20–21 to 20–48) with revisions of Article 802—Reserve for Retirement, Article 803—Insurance, and Article 1005—Payment in Legal Tender.

The committee recommends that the Agreement for Cab Stand and Baggage Transfer Privileges (Manual pages 20–48.1 to 20–48.3) be reapproved with the addition of a new clause entitled Independent Contractor.

The committee recommends that the Agreement for Joint Use of Passenger Station Facilities (Manual pages 20–47 to 20–51) be reapproved without change.

JOINT PASSENGER TERMINAL AGREEMENT

802—Reserve for Retirement

It is recommended the article be changed by addition of the underscored words to conform to ICC regulations. No deletions in the present text are made.

In lieu of the annual depreciation charge applicable to all classes of depreciable road property, in accordance with ICC classification, there shall be created under direction of the Board of Directors and as fixed by said Board of Directors from time to time, a fund representing a reserve for retirement and replacement of physical parts of the terminal except land, and such fund shall be equitably divided between the Passenger Station, Equipment Terminal and other separate facilities and shall, with accumulated interest, cover the cost of retirement or replacement of the separate parts of the terminal on the expiration of their useful life. The annual depreciation as referred to herein or the amounts necessary for the creation of this fund shall be a proper charge for the use of the terminal or parts thereof and charged against the companies using the same.

803—Insurance

The following change is recommended.

To be deleted

Insurance shall be carried at all times during construction and after completion in proper kinds, classes and amounts, so as to provide adequate protection against loss from fire, theft, etc., this insurance shall be carried with a commercial insurance company, or by arrangement through the insurance departments of the Companies, as approved by the Board of Directors.

Proposed form

Insurance shall be carried at all times during construction and after completion. It shall be of the proper kinds, classes and amounts, so as to provide adequate protection against loss from accidents, injuries, deaths, property damage, fire, theft, etc. Insurance shall be carried with a commercial insurance company (Workmen's Compensation Insurance in State Insurance Fund where applicable) or by arrangement through the insurance department of the companies, as approved by the Board of Directors.

1005—Payment in Legal Tender

The following change is recommended.

To be deleted.

All of said payments to be made by the Companies to the Terminal Company shall be made in lawful gold coin of the ....., of the present standard of weight and fineness.

Proposed form.

All of said payments made by the Companies to the Terminal Company shall be made in legal tender of the United States.

FORM OF AGREEMENT FOR CAB STAND AND BAGGAGE TRANSFER PRIVILEGES

A new article to be inserted in the agreement following Article 13 is recommended.

14—Independent Contractor

The Company reserves no control whatsoever over the employment, discharge, compensation of or services rendered by the Cab Company's employees, and it is the intention of the parties to this agreement that the Cab Company shall be and remain an independent Cab Company, and that nothing in this agreement contained shall be considered as inconsistent with that status. The Cab Company agrees to pay all contributions measured by the wages of its employees required to be made under the State and Federal Unemployment Compensation Insurance, Social Security or Retirement laws, applicable to the work performed hereunder by the Cab Company and it accepts exclusive liability for said contributions; the Cab Company further promises and agrees to indemnify and save harmless the Railway Company, and its successors and assigns, from any and all liability arising therefrom.

The following articles will be renumbered:

Article 14 changed to 15.

Article 15 changed to 16.

Report on Assignment 2

FORM OF CONSTRUCTION CONTRACT FOR MINOR PROJECTS

L. A. Olson (chairman, subcommittee), E. H. Barnhart, H. F. Brockett, J. S. Lillie, C. E. McCarty, W. L. Mogle, A. B. Montville, O. K. Morgan, W. G. Nusz, H. A. Palmer, G. W. Patterson, W. M. Post, B. M. Stephens, J. L. Way.

Last year your committee presented as information, a tentative draft of Form of Construction Contract for Minor Projects (Proceedings, Vol. 48, 1946, pages 284 to 288, incl.), and requested comments and criticisms thereon. This form of contract with minor revisions is now submitted with the recommendation that it be adopted and published in the Manual.

FORM OF CONSTRUCTION FOR MINOR PROJECTS

THIS CONTRACT, made this ..... day of ..... 19 ...., by and between ....., a corporation organized and existing under the laws of the State of .....

hereinafter called the Company and .....
hereinafter called the Contractor.

WITNESSETH: That, in consideration of the covenants and agreements herein contained, to be performed by the parties hereto, and of the payments hereinafter agreed to be made, it is mutually agreed as follows:

The Contractor shall furnish all of the materials, superintendence, labor, tools, equipment and transportation, except as hereinafter specified, and shall execute, construct and finish in an expeditious, substantial and workmanlike manner, to the satisfaction and acceptance of the Chief Engineer of the Company, all of the work required for .....
.....
in accordance with the plans dated ..... 19 ...., and described .....
.....
.....
and the Specifications, dated ....., 19 ...., all of which are incorporated herein and made a part hereof by reference.

The work covered by this contract shall be commenced on or before the ..... day of ..... 19 ...., and shall be completed on or before the ..... day of ..... 19 .....

Extra work may be done under this contract if authorized in writing by the Company's Chief Engineer at lump sums, unit prices or cost plus terms as mutually agreed upon between the Company's Chief Engineer and the Contractor.

1. Independent Contractor

The Contractor shall assume exclusive control over the employment, discharge, compensation of and services to be rendered by his employees and in the selection of methods and direction of the work and shall accept full responsibility for the results obtained, being governed by the plans and specifications hereto attached or made part of this contract, or as the same may be changed under the provisions of paragraphs numbered 3 and 4 hereof. It is the intention of the parties to this contract that the Contractor shall perform the work in the capacity of an independent contractor and that nothing contained in this contract shall be construed to be inconsistent with that status.

2. Contractor's Understanding

It is understood and agreed that the Contractor has, by careful examination, satisfied himself as to the nature and location of the work, the conformation of the ground, the character, quality and quantity of the materials to be encountered, the character of equipment and facilities needed preliminary to and during the prosecution of the work, the general and local conditions, and all other matters which can or may in any way affect the work under this contract. No verbal understanding, agreement or conversation with any officer, agent or employee of the Company, either before or after the execution of this contract, shall affect, alter or modify any of the terms or obligations herein contained.

The Contractor shall assume all risk, loss or damage from whatever cause to the tools, implements, machinery or materials owned by the Contractor, or in his possession while the same shall be on or near the premises where the said work is to be undertaken and performed by the Contractor, and the Contractor shall protect, indemnify and save the Company, its successors or assigns harmless from any and all claims, demands or suits on account of or arising from any such loss or damage.

3. Changes

The Company shall have the right to make any changes that it may deem necessary or desirable in the work to be undertaken, either before or after its commencement, and such changes shall in no way affect or void the obligations of this contract. If such changes result in any change in the cost of the work, an equitable adjustment shall be made by the Chief Engineer to cover the same, but the Contractor shall not claim nor be entitled to, and hereby waives, compensation for anticipated profits.

4. Inspection and Status of the Chief Engineer

The work shall be subject at all times to the inspection, acceptance or rejection of the Chief Engineer or his duly authorized agents. It is mutually agreed that the Chief Engineer shall in all cases determine the amount or quantity of the various kinds of work and the quality of materials and workmanship to be paid for under this contract, and he shall decide all questions which may arise relative to the work covered by this contract. Any doubt as to the meaning of the specifications and the drawings and any obscurity or discrepancy as to their wording and intent will be determined by the Chief Engineer and his determinations shall be final and binding on both parties to this contract. The Chief Engineer may amend or correct any errors or omissions in the plans and specifications when such amendments or corrections are necessary to make definite the intent indicated by a reasonable interpretation of the requirements of the contract.

5. Liability, Permits, Licenses, and Insurance

The Contractor shall assume all liability for, and indemnify and save the Company, its successors or assigns, harmless from, any and all claims, demands, and suits arising out of State or Federal Statutes, or at common law, in connection with any injury to persons including death resulting therefrom or loss of and damage to property, sustained by the parties to this contract or any of their officers, agents or employees, or by third parties, arising out of, or occuring in connection with, or in any way relating to, the work hereby undertaken by the Contractor.

Before doing any work under this contract the Contractor at his own expense shall secure and keep in effect until the entire work is completed and accepted the following:

(a) All permits, licenses and authorizations required by Federal, State, County or Municipal authorities. He shall assume payment of salaries and expenses of city and other public inspectors, policemen or officers which may be required in connection therewith.

(b) Fire insurance in the name of and payable to the Company for the benefit of the Contractor or the Company as the Chief Engineer shall find their interests to appear. Such policies to cover such structures or structural material and supplies on hand and subject to loss or damage as a result of fire, in such amount as necessary to cover their value.

(c) Workmen's Compensation insurance covering employees of the Contractor or any subcontractor, as required by the State or States in which the work is to be performed, so that the Company shall be fully protected from any liability or claims for damages for personal injury, including death, which may arise while engaged upon the work covered by this contract. The Contractor shall submit to the Chief Engineer evidence by certificate that such insurance in satisfactory amount is in force.

(d) Public Liability Insurance, Standard, Intermediate or Full Coverage, whichever form of coverage the Chief Engineer designates, shall be furnished in amounts of $....., $....., and Property Damage Insurance in amounts of $....., $.....

(e) Contractor's Contingent Public Liability and Property Damage Insurance, if there are one or more subcontractors, in the same amounts as required in (d) above.

Policies required in (d) and (e) shall be endorsed to cover the collapse and explosion hazard in addition to all other hazards unless endorsement be waived by the Chief Engineer, and shall expressly provide that if during the course of this work watchmen, flagmen or other employees of the Company are loaned or assigned to the Contractor in connection with this contract, such employees, while so engaged, shall be considered employees of the Contractor for the purpose of this insurance.

All the policies must be written by reliable and well-rated companies acceptable to the Chief Engineer. The policies shall be so written that they protect both the Contractor and the Company against any action which may be instituted against either of them. Certified copies of all policies shall be submitted to the Chief Engineer for approval. When approved they shall be retained by the Company and the Contractor notified of their approval. Notice of cancellation of policies shall be forwarded to Chief Engineer.

See Note (a) below.

6. Unemployment, Social Security and Retirement Insurance

The Contractor agrees to pay the contributions measured by the wages of his employees required to be made under the Unemployment Compensation Insurance, Social Security and Retirement Laws or similar laws, State and Federal, applicable to the work undertaken by the Contractor or his subcontractors, and to accept exclusive liability for said contributions. The Contractor further agrees to protect, indemnify and save harmless the Company, its successors, or assigns from any and all liability arising therefrom.

7. Performance Bond

Should the Company require the Contractor to post a Performance Bond it will be necessary for the Contractor to qualify and procure the same from an acceptable bonding company and the cost of such bond will be paid for by the Company.

8. Watchmen and Work Train Service

The Company will, without cost to the Contractor, furnish all flagman, watchman and pilot service which, in its opinion, is required to protect the operation of its facilities. Any work train service required in connection with the work covered by this contract will be furnished by the Company at the expense of the Contractor.

9. Term of Payment

Note: Delete any of the following paragraphs that do not apply:

(a) The Contractor shall furnish all transportation, equipment, labor and materials required in the performance of its undertakings hereunder for a lump sum price of .....

.....

which the Company agrees to pay and the Contractor agrees to accept in full payment for the work.

(b) The Contractor shall furnish all transportation, equipment, labor and materials required in the performance of his undertakings hereunder according to unit prices which are set up in Schedule "A" attached hereto, which sums the Company agrees to pay and the Contractor agrees to accept in full payment for the work.

(c) For any extra work authorized under this contract on a cost plus percentage basis, the Company will pay to the Contractor the sum of the actual net cost of items, as hereinafter specified, paid by the Contractor in accordance with the provisions of this contract in the accomplishment of the work, plus fixed percentages for overhead, profit and handling and supervision of subcontract work.

(1) Equipment rental.

(2) Materials—The Material cost shall be the actual costs to the Contractor of materials entering into the work covered by this contract, as evidenced by the correct receipted bills rendered by the dealer to the Contractor and approved by the Engineer.

Any trade discount, rebate or commission granted to the Contractor or any employees shall be credited to the cost, except that cash discounts for prompt payments are for the benefit of the Contractor.

The cost of materials and tools properly purchased for the work but not actually incorporated therein shall be the net first cost less the sale price or market value at the termination of the work, as approved by the Chief Engineer.

(3) Labor—The labor cost shall be the actual payroll costs for all labor employed by the Contractor in connection with the work covered by extra work order.

(4) Compensation and Liability Insurance—Actual cost of the insurance to the Contractor.

(5) Overhead ..... percent of item (3).

(6) Proft ..... percent of the sum of items (2) to (5) inclusive.

(7) Subcontracts—The cost of subcontracts shall be the actual cost shown by original bills, rendered by the subcontractor to the Contractor and approved by the Chief Engineer.

(8) Handling and supervision of subcontract work ..... percent of item (7).

The Contractor shall, if requested to do so, give the Company access to his books and records for the purpose of verifying the bills for work done on a cost plus percentage basis. See note (b) below.

10. Monthly Payments

The Company upon requisition by the Contractor will make monthly payments on account of the contract for all work completed less ten (10) percent and all previous payments. Such payments shall in no case be taken as an acceptance of the work or a release of the Contractor from responsibility therefor.

11. Final Payment

Before final payment is made, the Contractor shall submit evidence satisfactory to the Chief Engineer that all payrolls, material bills, and other indebtedness of the Contractor and his subcontractors connected with the work have been paid. After completion of the work and acceptance by the Company and upon requisition by the Contractor the Company will pay within thirty (30) days all monies due and owing to the Contractor for work done under this contract.

See Note (c) below.

The contract shall inure to the benefit of and be binding upon the legal representatives and successors of the parties respectively.

A

In Witness Whereof, the parties hereto have executed this agreement in ....., the day and year first above written.

Attest:

.....Company

..... By.....

Secretary

Witness..... .....Contractor

By.....

Note (a)—Satisfactory automobile insurance covering the operation of all motor vehicles operated on, about, or in connection with the work may be desired.

Note (b)—Information to be Furnished by Contractor.

The Contractor, along with his bid or prior to the award of contract, shall furnish the Company the following information:

(a) List of equipment and rate of pay for each item.

(b) Classification of labor and rate of pay for each classification.

(c) List of subcontractors.

(d) Percentage for overhead.

(e) Percentage for profit.

(f) Percentage for supervision and handling of subcontracts.

Note (c)—Termination clause. Should a termination clause be desired, see Section 29. Suspension of Work, in Form of Construction Contract.

Report on Assignment 3

Form of Agreement for Construction of Stop Log or Other Structures for Flood Control

G. W. Patterson (chairman, subcommittee), E. H. Barnhart, J. W. Hayes, C. J. Henry, W. D. Kirkpatrick, J. F. Marsh, A. A. Miller, W. L. Mogle, A. B. Montville, O. K. Morgan, F. L. Nicholson, C. B. Niehaus, W. G. Nusz, L. A. Olson, W. M. Post, Bruce Shaffner, B. M. Stephens, J. L. Way.

Your committee presents a draft of form of agreement for construction of stop log or other form of agreement for construction of stop log or other structures for flood control. Because of the current need of a form of agreement for construction of stop log or other structures for flood control, your committee presents such a form with the recommendation that it be adopted and published in the Manual.

FORM OF AGREEMENT FOR CONSTRUCTION OF STOP LOG OR OTHER STRUCTURES FOR FLOOD CONTROL

THIS AGREEMENT, made this ..... day of ....., 19 .... by between ....., a corporation existing under the laws of the State of ....., hereinafter called the Company, and ....., hereinafter called the Contractor.

Witnesseth That:

Whereas, as part of a Federal flood control project, known as ...., it has been decided that certain closures across the right-of-way and tracks of the Company are necessary and practicable, and

WHEREAS, the WAR DEPARTMENT, CORPS OF ENGINEERS, UNITED STATES ARMY, has entered into an agreement with the Company dated ....., 19 ...., and further identified as ....., covering an easement for said closures upon the property of the Company, and

WHEREAS, the WAR DEPARTMENT, CORPS OF ENGINEERS, UNITED STATES ARMY, has entered into a contract with the Contractor dated ....., 19 ...., and further identified as ....., covering the construction of the said closures, and

WHEREAS, the Contractor desires the right to enter upon the property of the Company and proceed with said construction,

NOW, THEREFORE, in consideration of the mutual covenants herein stipulated to be kept by the parties hereto, it is agreed as follows:

1. The Company hereby grants to the Contractor the right to enter upon its right-of-way and to proceed with the construction of closures herein contemplated, subject to the terms and conditions herein set forth.

2. The following identified plans, prints of which are attached hereto, are made a part hereof:

.....

.....

3. All work in connection with the construction of the closures shall be done at the sole cost and expense of the Contractor in such manner as not to interfere with or impair the safe and continuous operation of the railroad of the Company. All work shall be subject to the approval and meet with the acceptance of the Chief Engineer of the Company. The Contractor shall give the said Chief Engineer at least fifteen (15) days' notice in writing before commencing any operations upon the property of the Company.

4. The construction of the closures will involve supporting the tracks of the Company. The Company will arrange to install temporary supports for its tracks, will maintain said supports for the entire period of construction and will remove supports after completion of construction, and the Contractor hereby agrees to reimburse the Company for all cost incurred by it in connection therewith.

The Contractor further agrees to reimburse the Company for the cost to the Company of all engineering, inspection, flagging and other protection which the Chief Engineer of the Company shall determine from time to time to be necessary for the proper operation of its trains and the protection of its property, prior to and during the construction of the said closures and during construction, maintenance and removal of temporary support structures.

In the event the relocation or maintenance of existing pole lines or the splicing of cables is involved, the Company reserves the right to perform the work with its own forces, or other forces employed by it, and the Contractor shall reimburse the Company for the cost thereof.

The Company reserves the right to repair any damage to its roadbed, tracks or structures which may be caused by operations or negligence of the Contractor in connection with the construction herein contemplated and the Contractor hereby agrees to reimburse the Company for the entire cost thereof.

"Cost" as referred to herein shall include the actual cost of equipment, labor and materials plus ..... (.....) percent on labor and materials for accounting and overhead, and shall also include payroll taxes, vacation allowances, insurance premiums and all other items properly chargeable thereto, bills covering which shall be paid by the Contractor promptly upon presentation.

5. The Contractor further agrees to abide by clearance requirements of the Company and of any public body having jurisdiction; also to abide by laws and ordinances

governing the storage of dynamite, gasoline or other explosives or inflammable materials, except that in no event shall such materials be stored within ..... (.....) ft. of the nearest track of the Company.

6. The Contractor shall indemnify the Company against, and save it harmless from, all loss, claims, damages, costs, or causes of action of whatsoever nature, arising from or growing out of injury to or death of any person or persons, or damage to or destruction of property of any person whomsoever, in connection with the construction of the herein contemplated closures, and operations adjacent and incident thereto.

7. The Contractor shall arrange for, procure and assume the cost of all permits, licenses and authorizations required by Federal, State or other governmental authorities, and assume payment of salaries and expenses of Federal, State and other public inspectors, policemen or officers which may be required.

8. Before performing any work on the property of the Company, the Contractor shall arrange for and procure the following insurance coverage and shall keep the same in effect until the entire work is completed and accepted:

(a) Fire Insurance in the name of and payable to the Company for the benefit of the Contractor and the Company as the Chief Engineer of the Company shall find their interests to appear. Fire insurance shall cover structures, and structural materials and supplies on hand which may be subject to damage as a result of fire.

(b) Workmen's Compensation Insurance covering employees of the Contractor or any subcontractor, as required by the State or States in which the work is to be performed, so that the Company shall be fully protected from any liability or claim for damages for personal injury, including death, which may arise while the Contractor is engaged upon the work covered by this agreement.

(c) Public Liability Insurance in amounts of $..... $....., and Property Damage Insurance in amounts of $..... $.....

(d) Contractor's Contingent Public Liability and Property Damage Insurance, if there are one or more subcontractors, in the same amounts as required in (c) above.

All the policies must be written by reliable and well-rated companies, acceptable to the Company. The policies shall be so written that they protect both the Contractor and the Company against any action which may be instituted against either or both of them. Certified copies of all policies shall be submitted to the Chief Engineer of the Company for approval. When approved they shall be retained by the Company and the Contractor notified of their approval. Notice of cancellation of policies shall be forwarded to the Chief Engineer of the Company.

9. Following the completion of the construction work herein contemplated the Contractor shall remove all equipment, materials and debris and in general restore the Company's property to a condition satisfactory to the Chief Engineer.

10. It is understood that the Company reserves no control whatsoever over the employment, discharge, compensation of or services rendered by the Contractor's employees and it is the intention of the parties to this agreement that the Contractor shall be and remain an independent contractor and that nothing contained in this agreement shall be construed as inconsistent with that status.

In Witness Whereof, the parties hereto have executed this agreement in ...., effective the day and year first above written.

Attest: .....Company

..... By.....

Title

Witness: .....

..... By.....

Title

Report on Assignment 4

Form of Agreement to Permit Subsurface Exploration by State or Other Governmental Agencies, on Railway Right-of-Way

A. B. Montville (chairman, subcommittee), H. F. Brockett, G. K. Davis, J. W. Hayes, C. J. Henry, W. D. Kirkpatrick, J. S. Lillie, J. F. Marsh, C. E. McCarty, A. A. Miller, F. L. Nicholson, C. B. Niehaus, L. A. Olson, H. A. Palmer, G. W. Patterson, Bruce Shaffner, B. M. Stephens.

Your committee submits the following tentative draft of agreement as information.

At the present time the Manual does not contain a form of agreement permitting subsurface exploration by state or other governmental agencies, on railway right-of-way. The committee has drafted a form of agreement which it believes will fulfill requirements of granting permission by the railway to permit subsurface exploration on its right-of-way. Each member of the association who is interested in the tentative draft of the agreement as prepared is urged to give your committee the advantage of his criticisms and suggestions.

FORM OF AGREEMENT TO PERMIT SUBSURFACE EXPLORATION BY STATE OR OTHER GOVERNMENTAL AGENCIES, ON RAILWAY RIGHT-OF-WAY

THIS AGREEMENT, made this ..... day of ....., 19 ...., by and between the ....., a corporation of the State of ....., with its principal office at ..... hereinafter referred to as the Company and the ...., hereinafter referred to as the Agency.

WITNESSETH:

WHEREAS, the Company is the owner of certain lands in the Town of ...., County of ....., State of ....., and

WHEREAS, for the purpose of ascertaining subsoil conditions, the Agency is desirous of making certain borings on the property of the Company in the vicinity of Mile Post ..... of the Company's railroad, in the Town of ....., County of ....., and State of .....

NOW, THEREFORE, in consideration of the premises and the sum of One Dollar ($1.00) by each to the other in hand paid, the receipt of which is hereby acknowledged, the parties hereto agree as follows:

1. The Company hereby grants to the Agency authority to enter upon its property at the mile post described above and to drill and make such borings in such manner and at such locations as may be agreed upon between the Agency and the Chief Engineer of the Company.

2. The Agency agrees to exercise all reasonable care and to take such precautions as the Chief Engineer may deem necessary to properly protect the Company's facilities and operation of its trains. The Company reserves the right to make inspections of all drillings or borings to determine to its satisfaction that terms of the agreement are being complied with. The Agency hereby agrees to reimburse the Company for all reasonable costs and expenses incurred by the Company in affording such protection during the progress of the work as in the opinion of the Chief Engineer may be necessary.

3. The Agency shall indemnify the Company against and save it harmless from all loss, claims, damages, costs, or causes of action of whatsoever nature, arising from or growing out of injury to or death of any person or persons, or damage to or destruction of property of any person whomsoever, in connection with the herein contemplated work, and operations adjacent or incident thereto, arising in any way out of the performance of the work for which the permission herein is granted.

4. Upon completion of the work, the Agency shall restore the premises to their original condition, or a condition satisfactory to the Chief Engineer.

5. The covenants, terms and agreements herein contained shall be binding upon and inure to the benefit of the parties hereto and their respective successors and assigns.

In Witness Whereof, the parties hereto have executed this agreement in .... on the day and year first above written.

.....Company

By.....

Attest:

.....

Secretary

.....Agency

Witness:

.....

Report of Committee 22—Economics of Railway Labor

J. S. McBride,
Chairman,
Lem Adams
C. W. Baldridge
E. T. Barrett
E. J. Bayer
J. G. Begley
F. J. Bishop
W. H. Brameld
E. J. Brown
F. G. Campbell
H. G. Carter
H. A. Cassil
J. B. Clark
W. E. Cornell
P. A. Cosgrove
W. T. Donoho
J. P. Ensign
H. W. Flemming
C. G. Grove
C. T. Gunsallus
C. C. Haire
N. D. Howard
W. M. Jaekle
H. E. Kirby
L. A. Loggins
Roy Lumpkin
J. B. Martin*
E. H. McIlheran
A. K. McKeithan, Jr.
E. C. Vandenburgh,
Vice-Chairman,
F. R. Michael
W. H. Miesse
H. L. Miller
G. M. O'Rourke
W. G. Powrie
A. G. Reese
R. L. Schmid
G. L. Sitton
G. M. Strachan
W. H. Vance
H. J. Weccheider
Edward Wise, Jr.
C. R. Wright
Committee

* Died July 11, 1947.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.

2. Analysis of operations of railways that have made marked progress in the reduction of labor required in maintenance of way work.
   Progress report, presented as information ..... page 136

3. New methods and labor saving equipment to offset increased costs.
   Final report, presented as information ..... page 137

4. Labor economies derived from continuous welded rail in special locations, collaborating with Committee 4.
   Final report, presented as information ..... page 139

5. Organized training of supervisors.
   No report.

6. Labor economies to be derived by adherence to safety precautions.
   Final report, presented as information ..... page 141

7. Track maintenance in CTC territory.
   No report.

The Committee on Economics of Railway Labor,
J. S. McBride, *Chairman.*

AREA Bulletin 470, December 1947.

James B. Martin

James B. Martin, who had been a member of the Association since April 1924, died on July 11, 1947. He was born at Espyville, Pa., on October 1, 1882 and entered railroad service with the Lake Shore & Michigan Southern Railway, predecessor of the New York Central, in clerical and accounting work and was successively member of engineering corps, assistant roadmaster, roadmaster, supervisor of track and general inspector of track until his retirement on September 30, 1942. After his retirement from railroad service he became associated with the Woodings–Verona Tool Works as a general inspector. He had been an active and valuable member of the Committee on Economics of Railway Labor for the last 12 years.

Report on Assignment 2

Analysis of Operations of Railways that have made Marked Progress in the Reduction of Labor Required in Maintenance of Way Work

W. E. Cornell (chairman, subcommittee), Lem Adams, J. G. Begley, F. J. Bishop, E. J. Brown, F. G. Campbell, H. A. Cassil, J. P. Ensign, H. W. Flemming, C. T. Gunsallus, C. C. Haire, N. D. Howard, H. E. Kirby, Roy Lumpkin, E. H. McIlheran, H. L. Miller, W. H. Vance, Edward Wise, Jr.

This report is presented as information. It describes an inspection of welded rail on the Delaware & Hudson Railroad on July 16, 1947, and presents some comparative figures on man-hours for maintenance.

The approximately 43 miles of welded track on the D. & H. comprises 11 separate locations, totalling 10,984 welds, of which 7277 are flash welds and 3707 are thermit welds. The first of the welded track laid on the D. & H. is 2 miles of 130-lb. RE rail laid at Albany in 1933. The remainder of the 43 miles is 131-lb. RE rail, the greater part of which was laid from 1935 to 1939.

A report on the original cost of this welding, together with similar welding costs on other roads, may be found in the Proceedings, Vol. 42, 1941, page 660.

The gross tons carried vary from approximately 37 million at an average of about 4 million per year to a maximum of around 264 million at an average of about 27 million per year.

Different types of ballast are used, including cinders, ore sand and crushed stone. The track structure consists of grade 4 and 5 ties at 20-in. centers with tie plates lagged to the tie with screw spikes and four spring-clips per tie serving both as hold-down fastenings and as anchors against rail running.

While there has been spot tamping on the welded track, it has not been surfaced out of face since its installation and as yet there is very little evidence of pumping ties and no marked indication of center bound track.

Experience on the D. & H. is that rail failures, including broken welds, are possibly less frequent than on similar rail and track of jointed construction and that the probability of buckled track presents no greater problem than may be expected on similar jointed track.

A total of 2.18 miles of welded track was removed in 1946 at two locations due to damage from a broken wheel; 0.60 miles was removed in 1947 because of wear of the low rail of curves; and 0.27 miles was transposed on curves in 1945.

Accurate records of maintenance man-hours are being kept on two comparably similar sections of track in the vicinity of Schenectady, N. Y., and also on two sections in the vicinity of Port Henry. The weighted averages of these man-hours for the various types of work and other relevant data are as follows:

COMPARATIVE MAINTENANCE MAN-HOURS

Period: January 1938 to December 1946 (weighted avg. 8.5 yrs.)
Test Stretches: 25.0 miles angle-barred 130 lb. and 131 lb. RE rail
19.1 miles continuously welded 131 lb. RE rail
Weighted average tonnage since laid, angle-barred—185,900,000
Weighted average tonnage since laid, welded-rail—131,520,000

	MAN-HOURS			
	Per Mile Per Year		*Per MGT Per Mile Per Year*	
	Angle-Barred	*Welded*	*Angle-Barred*	*Welded*
Lining and surfacing	433.5	241.4	24.08	17.24
Tightening track bolts	33.6	2.0	1.86	0.14
Tightening and renewing clips	35.6	38.7	1.98	2.76
Gaging	50.2	21.2	2.79	1.51
Replacing rail and cutting in closures	93.4	36.3	5.19	2.59
Miscellaneous	18.5	10.8	1.03	0.77
Total	664.8	350.4	36.93	25.01

Conclusion

Material savings in maintenance labor, running possibly as high as 30 percent or more, may be obtained from the use of continuous welded rail.

Report on Assignment 3

New Methods and Labor Saving Equipment to Offset Increased Costs

C. G. Grove (chairman, subcommittee), E. J. Bayer, J. G. Begley, F. J. Bishop, H. G. Carter, J. B. Clark, W. E. Cornell, P. A. Cosgrove, H. W. Flemming, N. D. Howard, Roy Lumpkin, W. H. Miesse, H. L. Miller, W. G. Powrie, A. G. Reese, G. M. Strachan, W. H. Vance, E. C. Vandenburgh.

This is a final report submitted as information. The subject of this report restricts the analysis to new methods and new equipment. Many worthwhile changes have been made in work equipment, although not many new machines have been produced. This report will therefore deal largely with refinement in methods and in the application of improved machinery.

To offset increases in costs, work must be accomplished in a more economical manner. Economies have been brought about in various ways, the avenue of approach being along the following lines:

1. *Improved Supervision.*—To achieve this some roads have proceeded as follows: (a) Organized informal schools under the direction of supervisors to instruct and develop trackmen for the positions of foremen, and to instruct machine operators in the care and

use of machines. (b) Set in motion plans to increase the wage rates of foremen so that the job will be more attractive compared with the positions of machine operator, welder, etc., where the responsibility is not so great. (c) Provide a definite program for developing promising foremen into assistant supervisors and supervisors, and a careful plan for recruiting technical men with a comprehensive program of training so that they may develop into supervisors of track and be available for promotion.

2. *Careful Planning and Programming of Work.*—Much money is wasted by lack of proper planning and programming of work. Careful study ahead of time of how the work will be done and what machines are to be used, will cut production costs amazingly and insure the smooth and on time accomplishment of the task, which will do much, without penalty time, to increase the confidence of a group and make them more effective. With satisfied and enthusiastic men there is less turnover and the work is done at less cost. Long range construction and maintenance programs throughout the year can and are being accomplished at less cost and on time by such planning.

3. *Applying Material at Less Cost.*—This saving can be brought about by having men well organized and imbued with a spirit of enthusiasm for their work. Machines of all kinds are constantly being used more effectively. Careful analysis of train movements and the interested cooperation of the operating people will insure a maximum occupancy of tracks for the work operations and increase production figures enormously. There is an opportunity on every railroad to augment production by enlisting the cooperation of the transportation officers.

4. *Use of Equipment to Offset Increased Costs.*—To describe and list all the equipment that is now used with increasing efficiency and a resultant reduction in costs would be a well nigh impossible task and would not serve any good purpose. Most of the improvements are known by many, but some outstanding developments of the year in cost reducing equipment are: Improvements in the design, operation and production of crib cleaning equipment; increasing utilization of trucks in place of motor cars to transport men and material, and in some cases, abandonment of camp outfits with cooks and attendants made possible by the use of properly scheduled trucks; utilization of machines such as weed burners for snow fighting and snow flanger cars for ballast leveling; improved design of on-track power ballasting machines that have increased production and the quality of the work by large increments (the off-track work of widening fills and cuts to help in fighting snow); greater efficiency due to the use of off-track equipment throughout the year rather than seasonally, such as the conversion of tractor mowers to rotary snow brooms; crawler air compressors used for tamping track in the summer and used again in the winter for gaging and anchor spiking; careful analysis of snow handling costs; and the greater use of switch heaters and snow melters in yards.

These uses of machinery described, supplemented by many other up-to-date methods such as extensive and improved ballast cleaning, roadbed grouting, drainage projects, etc., all add up to less maintenance costs.

Conclusions

This review of this phase of maintenance of way work shows that steady strides are being made in reducing costs as indicated generally by:

1. Improved supervision.
2. Careful planning and programming of work.
3. Applying material at less cost.
4. Use of equipment to offset increased cost.

These tangible ways of reducing costs can be well supplemented by improvement in "esprit de corps" and morale, a field which holds promising dividends and should not be neglected.

Report on Assignment 4

Labor Economies Derived from Continuous Welded Rail in Special Locations

J. P. Ensign (chairman, subcommittee), Lem Adams, C. W. Baldridge, F. G. Campbell, H. G. Carter, P. A. Cosgrove, W. T. Donoho, H. W. Flemming, W. M. Jaekle, L. A. Loggins, E. H. McIlheran, W. H. Miesse, G. L. Sitton, G. M. Strachan, W. H. Vance, E. C. Vandenburgh, Edward Wise, Jr., C. R. Wright.

This is a final report submitted as information.

The problems bearing on the proper maintenance of rail joints have long been actively discussed, as indicated by past consideration of methods of maintaining track joints, types of bars, etc. The impact of the wheel load at the joint is a problem, and a remedy is to eliminate the joint.

That the pressure butt-welding of rail ends is practical can be attested to by various railroads; one in particular stating that it had installed 3230 welded joints since 1939; without a single failure, and another, 6314 between 1941 and 1947, without a failure. The majority of the above rail was laid in what is considered special locations.

The cost of a bolted joint in main track during the life of the rail can be closely estimated, disregarding all surfacing costs. Many railroads install two sets of joint bars with bolts, washers, bonds, etc., while rail is in main track, at special locations, including building up rail ends, at a cost of from $12 to and exceeding $20, and on some roads the rail has been removed from track, cropped and replaced in main track with resultant heavy expenditures. The cost of surfacing, shimming, digging out mud, removal of street or road crossings, and tunnel hazards, varies extensively and no attempt is made to evaluate this as there are too many contributing factors. If joint maintenance could be eliminated at places where effective drainage or means of surfacing cannot be assured, the tasks of shimming, bonding, joint bar and bolt replacement, building up rail ends by welding, and other operations which are necessary to maintain rail joined by conventional methods are no longer necessary.

In considering the material costs of laying conventional track, together with the cost of maintaining conventional joints, it would be well to balance the cost of butt-welding a rail joint together with the additional cost of installation of all-welded rail. The cost of welding, as submitted by several roads, varied from $8.58 to $19.28 per welded joint, using 1946 figures. In the case presented by the higher value, only one mile of track was welded and the figure also includes the cost of setting up and the removal of the necessary equipment. Quoting this same road, "on a large enough scale, it should be possible to bring down installation costs to a level where they would favorably compare with those of conventional bolted tracks, disregarding the benefits realized from the elimination of joints and the maintenance savings so effected, and the installation of welded track would thus seem to be economically justified." Very little information is available on a comparison of costs reflected in the laying of bolted rail and the laying of rail after it is welded in long lengths, but what is available reflects that such costs are far from prohibitive and would be absorbed by a longer life in main

track of the welded rail. Several roads have indicated a longer life of from three to five years can be expected.

Information received from various railroads revealed that butt-welded rail is being laid in special locations as follows, and for the following reasons:

1. In street and grade crossings to avoid the expense of the removal of crossing for repairs to the joint and for surfacing,
2. Through tunnels to avoid the maintenance of the joint and surfacing,
3. Locations where track subgrade is in an unstable condition, requiring excessive maintenance of the joint and surface,
4. On bridges and viaducts to eliminate impact, joint maintenance, and in special cases the elimination of objectionable noise,
5. Along and through station platforms because of drainage conditions,
6. Over track scales and track pans where vibration affects scales and likewise contributes to the deterioration of track pans,
7. In the vicinity of coaling and water plants, inspection pits, turntables, engine-houses and car retarders, principally to decrease deterioration of substructure and to avoid the use of bars for clearance of mechanism on car retarders.

Mention should be made of two railroads where substantial savings have been effected by the use of 78-ft. welded rail. In one instance two miles of 78-ft. welded rail was laid on poor subgrade and during the first 7½ years the labor for surfacing, lining and tightening bolts averaged 640 man-hours per mile as compared to 925 man-hours per mile of conventional adjacent bolted track of 39-ft. rails. Undoubtedly further savings will be realized by avoiding the renewal of joint bars. This same road reports the life of 131-lb. RE section rail in main track at these locations as 15 years, and possibly 25 years in secondary or yard tracks where the savings will continue. Enthusiastic reports were received from both railroads as to the value of this 78-ft. rail.

However, some of the economies derived from the use of all-welded rail mentioned by various railroads are as follows:

1. The annual saving for surfacing joints through street and road crossings amounts to 54 man-hours per joint,
2. The annual saving for surfacing in the vicinity of coaling and water stations amounts to 31 man-hours per joint,
3. The annual saving per mile in a tunnel has been given by one road as 360 man-hours per year over a period of three years, and in addition, at this same location the life of the rail is expected to be extended from six years for conventional track to ten years for all-welded track,
4. One road installed 4¾ miles of all-welded rail in a double track tunnel in 1942, and has estimated the life of the rail in conventional track at seven years and anticipates a life of 12 years for all-welded track at the same location. This same road has not kept an accurate record of expenditures for surfacing track at this particular location but offers the conclusion that there will be at least 35 percent less maintenance due to the welding of the rail joints.

There also has been mentioned a possible lengthening of life of joint ties and bridge ties but this is somewhat open for argument depending somewhat on type of track construction.

In consideration of the adaptability of any location for an installation of all-welded rail, tonnage, curvature and rail section should be carefully considered.

Conclusions

1. Definite labor economies have been obtained by the use of continuous welded rail in special locations such as street and highway grade crossings, tunnels, station grounds, in the vicinity of coaling and water stations, etc.
2. The labor economies to be obtained will vary with local conditions.

Report on Assignment 6

Labor Economies to be Derived by Adherence to Safety Precautions

E. J. Brown (chairman, subcommittee), C. W. Baldridge, W. H. Brameld, W. T. Donoho, C. G. Grove, C. T. Gunsallus, C. C. Haire, N. D. Howard, L. A. Loggins, A. K. McKeithan, Jr., F. R. Michael, G. M. O'Rourke, A. G. Reese, R. L. Schmid, H. J. Weccheider, C. R. Wright.

This is a final report submitted as information.

General

Safety has always been the watch word of railroad operation and maintenance. In the latter, adherence to strict performance of set rules for doing work not only avoids injury but increases efficiency.

There are many important phases of safety. For example, the adverse effect that an injury has on a worker's family is significant, and much thought should be given to it. The subject is a broad one, and the scope of this discussion is limited to only one phase. The effect of accidents upon the productive capacity of the men and equipment, and what can be done to reduce such accidents to a minimum. To explore the by-paths of safety would require a series of articles instead of only one.

When safety precautions are not adhered to, the following losses are sustained:

1. Actual time lost by the injured person.
2. Actual time lost by the gang while transporting the victim to a doctor or a hospital.
3. Lost efficiency of the gang due to the bad effect which accident has on morale.
4. Lost efficiency of the gang because of being deprived of the use of the motor car or other equipment damaged or destroyed.
5. Money paid to the injured person or to his family.
6. Repair or replacement costs of equipment damaged or destroyed.

For many years industry has been fully aware of the importance of safety to its employees. It realizes, among other things, that the efficiency of a gang can be crippled by injuries; that when an injury affects an employee after he returns to work, industry suffers as well as the employee because he cannot carry his full load; that when labor is scarce it must do its utmost to have as many of its employees as possible on the job full time, and that compensation payments can become a very heavy burden. All these factors affect industry economically, but consideration must also be given to the fact that, when industry shows considerable interest in the safety of labor, a better understanding results as a whole.

The first step to instill the meaning of safety in the minds of employees is to educate the supervisor fully to recognize its true meaning. He must be a leader of his men and be able to discriminate between men in accordance with their several natures. He must

be a teacher, and his influence over men under his jurisdiction in matters of safety must start the minute the new man goes to work. The supervisor is a human engineer who observes unsafe conditions and corrects them so the men will not suffer injury.

In his association with the employees the supervisor should give consideration to the following items:

1. Adherence to rules.
2. Adaptability of the men to the job assigned.
3. General health of the men.
4. Past injury records.
5. Elimination of hazards.
6. Solicitations of safety suggestions of all kinds.
7. Investigation of all injuries and near injuries.
8. Discourage horse play.
9. Wearing of suitable clothes and goggles.
10. Inspection of tools.

When the supervisor or foreman has chosen his gang and is prepared to go to work, a safety meeting of all employees should be called and the matter of organizing along safety lines laid before them. The men should be addressed on the subject of safety in simple language by an officer who knows their work and, in addition, is fully acquainted with the importance of safety practices.

The amount of efficient, safe and economical work produced by a man or a group of men is in direct proportion to the knowledge possessed of the work being performed or the machine being operated. Men who thoroughly understand their duties instinctively work in a safe manner themselves, and at the same time subconsciously watch the actions of their fellow workmen. A man who has to stop and think before making each movement is neither a safe nor a productive employee. His hesitation in movement can—and often does—result in nonproduction and the possibility of personal injury to himself or men working with him. An efficient supervisor will realize this factor and take steps to correct it.

Watch for Bad Habits

After the job is properly started, the supervisor should find and correct the unsafe acts before they develop into habits. Bad habits grow as a gradual process and it requires constant vigilance to prevent their development.

Corrective action should never be deferred. The first time a supervisor sees an unsafe condition or practice he is usually aware that something is wrong. If he does not take corrective steps immediately, each time he passes by the same hazard the danger will be progressively minimized in his mind until he ceases to consider it a hazard. If housekeeping is allowed to deteriorate, if men are not given full instructions in the safe performance of their jobs and are not constantly checked on methods of performance, injuries will inevitably result.

Safety and the Job are Inseparable

At times there is a great tendency to handle safety by itself, that is, separate and apart from the job. As a matter of fact, true safety is the very core of the ordinary day-by-day elements of railroad maintenance and operation.

Motor Cars Contribute to Accident Toll

Perhaps the most common accident and the one that involves not only property damage but also breaks down gang efficiency the most, is the motor car accident. When

a motor car is destroyed or damaged in an accident, the gang is seriously handicapped until a replacement can be made. Production is naturally retarded—in some instances quite seriously—to say nothing of the expense of repairing or replacing the equipment. If an injury is sustained, production is set back by the man-hours lost by the victim as well as by the loss of efficiency suffered by the gang due to the decline in morale induced by the accident.

Every man on a motor car should thoroughly understand his duties in handling the car under ordinary conditions as well as those required of him in an emergency, and he should be able to act subconsciously and without hesitation. It is the duty of the foreman or other person in charge of a motor car to see that tools or supplies carried on the car are loaded in a safe manner and that each man on the car places himself in a safe position.

Chief Causes of Accidents

Some of the most common injuries in the maintenance and engineering departments are as follows:

1. Motor car accidents:
   Collisions, derailments, setting motor cars on and off track, cranking engines.
2. Falls:
   Stumbling, slipping and tripping, falls from ladders, scaffolds, bridges, through cars, from motor cars and trailers.
3. Being struck by:
   Tools, flying spikes, bolts, chips, and falling objects.
4. Handling material:
   Carrying, pulling, piling, loading and unloading of rails, ties and bridge material.
5. Using tools:
   Chiefly when tools slip.
   Defective tools.

Ideas for Arousing Interest in Safety

Some of the schemes used to maintain interest in safety are:

1. Monthly reports showing:
   (a) The number of days elapsed in a supervisor's organization without a reportable personal injury, giving the date of the last reportable injury and showing the rank of each supervisor.
   (b) The number of employees working and the number wearing safety shoes; the greatest percentage giving the supervisor the top rank.
   (c) The position of each division in the competition for a maintenance of way trophy, based upon casualties per million man-hours.
2. Each casualty, large or small, is investigated by the supervisor. The result is broadcast to all employees to aid in preventing a recurrence.
3. Reportable injuries are analyzed by making a formal investigation. This action emphasizes to the entire force that the day is past when rule violations resulting in injuries and accidents will be dismissed lightly.
4. One practice is to place on each tool house on January 1 a metal sign reading "No Accidents This Year." The procedure is that when a foreman suffers an accident to one of his men, he must personally remove the sign and send it in to the supervisor. He restores the sign on January 1 of the following year. This

plan not only keeps the desire for no accidents constantly before the force, but advertises to others traveling over the road that the foreman at that point is a safe man.

5. The use of visual education.

Each injury should be considered potentially reportable, and every precaution taken to care for the injured person. He should be sent to a doctor immediately to prevent the possibility of loss of time due to infection. In many cases prompt action lessens the severity of the injury.

Each minor injury should be followed up and the man encouraged to return to work to avoid exploitation by the occasional malingerer. It is, of course, necessary to have the cooperation of the employee and company physician to secure the doctor's release.

Conclusion

Labor economy will be a natural result of, and in direct proportion to, the practical schooling in safety matters given to supervisors and their men. The educational program must be constant, analytical, and aggressive to be effective. Safety is a selling job and its success depends upon how well supervisory officers know the meaning of good safety practices. Thus, in order to sell safety, they must analyze every operation of every job under their control to determine how each move can be made with safety. This knowledge will enable them to do more than merely tell the men to be careful.

Report of Committee 29—Waterproofing

G. E. Robinson, *Chairman,*
J. P. Gallagher
W. G. Harding
M. L. Johnson
L. H. Laffoley
J. A. Lahmer
R. L. Mays
B. J. Ornburn
F. J. Pitcher
W. E. Robey
C. A. Whipple, *Vice-Chairman,*
T. M. von Sprecken
J. P. Walton
H. T. Welty
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including revisions of the Specifications for Bituminous Emulsions for Dampproofing, as shown below.

2. Waterproofing of railway structures.

   No report.

The Committee on Waterproofing,
G. E. Robinson, *Chairman.*

Report on Assignment 1

Revision of Manual

G. E. Robinson (chairman, subcommittee), J. P. Gallagher, W. G. Harding, M. L. Johnson, L. H. Laffoley, J. A. Lahmer, R. L. Mays, B. J. Ornburn, F. J. Pitcher, W. E. Robey, T. M. von Sprecken, J. P. Walton, H. T. Welty, C. A. Whipple.

Your committee recommends the following revisions of the Specifications for Bituminous Emulsions for Dampproofing which appear on pages 29–17 to 29–19 of the Manual:

I–1. Line 2, omit the words "steel and;" end of line 2 and line 3, omit the words "concrete surfaces."

III–6. Omit the last sentence of the first paragraph.

III–7. Paragraph 5, lines 2 and 3, omit "all metal surfaces that are not new and to"

III–9. Revise first paragraph to read as follows: "Emulsions which have been frozen shall not be used."

AREA Bulletin 470, December 1947.

In addition to the foregoing, the following editorial changes are recommended: Add the letters or words appearing in italics below:

I Scope

Lines 2 and 3 "emulsion*s*"

II Material

2. "Asphalt Emulsion*s*"
Line 1, "emulsion*s* (clay type) shall be *of* a steam refined"
Line 5, "Analysis of *the* emulsion ....."

3. "Coal-Tar Emulsion*s*"
Line 1, "emulsion*s*"

4–A. "The reaction of *the* emulsion ....."

C. Lines 1 and 2 "emulsion*s*"

J. Line 3, "emulsion*s* (but not into coal-tar emulsion*s*)"

III Application

6. Line 1, "The surfaces upon which *a* bituminous ....."
Line 4, insert comma after "or."

7. Paragraph 1, line 3, "emulsion*s*"
Paragraph 2, "emulsion*s*"
Paragraph 4, line 1, "When used on *new* concrete, ..."
Paragraph 4, line 2, "In no case shall *an* emulsion ....."

8. Paragraph 4, "When *an* emulsion ....."

9. Paragraph 1, "Emulsion*s*"

The committee recommends the following changes, omissions, and substitutions.

III–6. Paragraph 2, omit—"Cracks in walls or walls that have" and substitute therefor "Surfaces that have cracked, ..."

7. Line 2, omit the hyphen in "bristle brush."

III–7. Paragraph 3, line 2, change "the dry finger tip" to "a dry finger tip;" and change "will" to "shall."

9. Paragraph 2, line 2, change "it" to "the film."

Report of Committee 27—Maintenance of Way Work Equipment

EDGAR BENNETT, *Chairman,*
E. L. ANDERSON
C. M. ANGEL
R. M. BALDOCK
R. E. BERGGREN
W. R. BJORKLUND
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C. R. KNOWLES
JACK LARGENT
W. B. LEE
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J. C. RYAN
J. L. STARKIE
G. M. STRACHAN
M. C. TAYLOR
J. N. TODD
S. E. TRACY
E. G. WALL
G. R. WESTCOTT
A. H. WHISLER
F. F. ZAVATKAY
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, including recommended revisions ..... page 148

2. Standardization of parts and accessories for railway maintenance motor cars.
   Progress report, presented as information ..... page 149

3. Portable conveyors.
   No report.

4. Power ballasting machines.
   Progress report, presented as information ..... page 151

5. Snow removal equipment.
   Final report, presented as information ..... page 152

6. Power cribbing machines.
   Progress report, presented as information ..... page 158

7. Power spike machines.
   Final report, presented as information ..... page 162

8. Diesel engines.
   No report.

9. Flame cleaning equipment for steel bridges and buildings.
   Final report, presented as information ..... page 164

AREA Bulletin 470, December 1947.

10. Machinery and equipment for stabilizing roadbed.
Final report, presented as information ..... page 167

11. Ballast cleaning equipment.
Final report, presented as information ..... page 172

The Committee on Maintenance of Way Work Equipment,
Edgar Bennett, *Chairman.*

Report on Assginment 1

Revision of Manual

G. R. Westcott (chairman, subcommittee), E. L. Anderson, E. B. Harris, C. R. Knowles, F. H. McKenney, C. E. Morgan, R. A. Morrison, A. W. Munt, J. C. Ryan, J. N. Todd, F. F. Zavatkay.

On pages 27–9 and 27–10 of the Manual, under the title Methods of Maintaining Motor Cars there are set out certain principles pertaining to that subject. It is now recognized that this subject matter, while pertinent to the conditions of 20 years ago, is now out of date for the reasons that: (1) The maintenance of motor cars has now been submerged in the maintenance of work equipment generally, and (2) the care and operation of maintenance of way work equipment has a direct bearing on its maintenance.

Your committee, therefore, recommends the removal from the Manual of Methods of Maintaining Motor Cars now appearing on pages 27–9 and 27–10, and the substitution therefor of the following:

Care and Operation of Maintenance of Way Work Equipment

The varying conditions on different railroads do not permit the universal acceptance, in all details, of any specific outline of an organization for the use and maintenance of maintenance of way work equipment. In determining on each road the exact organization best adapted to produce maximum service at minimum cost from the work equipment that it has, the extent to which the work is mechanized, the type of organization set up for supervising the work of maintaining the property, and other conditions must be considered.

However, there are certain principles in the use and maintenance of work equipment the observance of which will be found desirable, if not essential, if the equipment is to be maintained and used economically. Especial attention is directed to the following:

1. The organization for maintaining maintenance of way work equipment should be headed by a practical railroad man, with sufficient executive ability and sound mechanical knowledge to supervise the maintenance and operation of all work equipment on the system. This superintendent of work equipment should have authority, and sufficient personnel, to institute and enforce regulations for the maintenance and operation of the equipment. His duties should embrace direct control of all mechanical details of the equipment, in both field and shop, the supervision of all maintainers, and the making of all reports. He should work closely with the maintenance of way supervisory forces in the assignment of the equipment, and collaborate with the purchasing and supply departments in the purchase of new equipment, and the purchase and distribution of supplies required for the maintenance of the equipment. A typical organization for

the maintenance of work equipment and an outline of the duties of each man may be found in the Proceedings, Vol. 47, 1946, pages 183–185.

2. Adequate instructions for the care and operation of maintenance of way work equipment should be issued. Such instructions are outlined in the Proceedings, Vol. 48, 1947, pages 1–121, and are published in handbook form as a supplement to the Manual, under the title Manual of Instructions for Care and Operation of Maintenance of Way Work Equipment.

3. Cooperation on the part of maintenance of way supervisory officers in seeing that instructions are carried out is of utmost importance. This cannot be secured unless each such officer is first impressed with the importance, to the work he is supervising, of keeping the equipment in operation.

4. Prevention of disabling conditions in any machine is as truly maintenance as is the correction of such conditions after they have developed; and prevention will save the loss of time required for repairs.

5. The need for repairs can be reduced by keeping the machine clean, inspecting it regularly, making needed adjustments promptly, and handling it carefully in operation.

6. Stores should be centrally located and adequately stocked so that repair parts, when needed, can be supplied with the least delay. The use of relief machines and power plants will reduce delays in the event of machine failures.

7. In scheduling the shopping of machines for major repairs consideration should be given to the capacity of the shop as well as the condition of the machine. Insofar as possible, machines used in seasonal work should be overhauled during the slack season.

8. Shops for the repair of roadway work equipment should be centrally located and entirely under the control of the maintenance of way department. Modern shop equipment suited to the work to be done should be provided. A list of desirable machinery and tools is shown in the Proceedings, Vol. 47, 1946, pages 186–192. This list may be modified to suit conditions on any railroad.

9. The expense of maintaining roadway work equipment can be reduced through the adoption by each railroad, of the fewest number of makes and types of machines required to meet its needs. Such a restriction to adopted standards will reduce investment in stock parts and lower maintenance costs.

10. Necessary reports and records should be prepared as a means of maintaining close check on the use being made of the equipment, the care being taken of it, and to assist in passing judgment on purchases of new equipment. Recommended Forms 2701–2719, incl., for these reports and records are shown in the Manual, pages 27–11 to 27–25, incl.

Report on Assignment 2

Standardization of Parts and Accessories for Railway Maintenance Motor Cars

S. E. Tracy (chairman, subcommittee), E. L. Anderson, W. R. Bjorklund, C. L. Fero, Jack Largent, E. H. Ness, John O'Farrell, C. H. Ordas, P. G. Petri, M. C. Taylor, J. N. Todd, A. H. Whisler.

This report is submitted as information with the recommendation that the subject be continued.

Limit of Wear on Pressed Steel Wheels

Pressed steel wheels as furnished by the manufacturers may be either ¼ in. or 5/16 in. in thickness.

Abnormal and premature wear of the wheel tread, throat and flange will occur if the motor car is not properly maintained. A car that is out of alinement; that has tight gage; that is operated with badly worn axle and bearing assemblies; that does not have, and hold during operation, the same distance between axle centers on both sides of the car, will be subject to excessive wear of the wheel flanges, a condition that can usually be detected by the short life of wheels or by the worn condition of the wheel flanges on opposite sides and opposite ends of the car.

Under normal operating conditions and with proper maintenance of the car, the metal in the wheel tread, throat and flange is slowly and uniformly reduced in thickness, finally reaching a point where the wheel is no longer fit for further service. Usually the wheel throat area will wear more rapidly than the flange or tread areas, resulting in cracks and finally in separation of the metal between the wheel flange and tread.

Overloading of push cars and trailers causes a deformation in the wheel plate and results in early failure of the wheel, usually identified by the appearance of a crack in the approximate center of the wheel tread.

It is the recommendation of your committee that:

1. A regular periodic inspection be made of motor car, trailer and push car wheels with a suitable gage by which the thickness of metal in the wheel tread, throat and flange can be determined.
2. Wheels be replaced when wear has reduced the plate thickness in one or more of these areas to ⅛ in.
3. Wheels be replaced when cracks have developed in one or more of these areas regardless of the plate thickness of the wheel in the area.
4. Wheels on drive axles be replaced in pairs of the same circumference.

Windshields and Cab Tops

Although the terms "windshield" and "cab top" are each used and accepted to designate a motor car accessory they are closely related in many particulars and for the purpose of this discussion are jointly considered.

Manufacturers now provide these accessories with such alterations as may be necessary to satisfy the requirements peculiar to each individual railroad. Additional types some of questionable design, are applied by the individual to whom the motor car is assigned. The differences in operating and climatic conditions between various railroads, and in many cases between districts on the same railroad, do not permit the universal acceptance of a specific current design.

Future developments may produce a light weight material readily adaptable to this service which will eliminate manufacturing difficulties and overcome present objections to such things as impairment of visibility, blind spots, excessive wind resistance, comparatively short useful life, lack of interchangeability, length of time involved to put on and take off to suit changing conditions, and the initial cost and upkeep.

It is the opinion of this committee that it is not necessary, desirable or economical to equip every motor car with either a windshield or a cab top regardless of the type of service to which it is assigned. There are many varying and changeable conditions and requirements of the service to which a motor car is assigned. The necessity for and the application of a windshield or a cab top must be governed by these conditions and requirements.

Windshields or cab tops with fixed immovable sides which almost or fully enclose the operator and other occupants on the car are not recommended.

Windshields or cab tops which fully enclose the operator and other occupants of the car are not recommended unless properly designed:

1. To prevent entrance of exhaust gas.
2. To permit each occupant to unload as quickly as if not in the enclosure.
3. To provide for clear visibility through the front, sides and rear of enclosure.

Electric Lights

It is the opinion of your committee that it is not necessary, desirable or economical to equip every motor car with an electric lighting system regardless of the type of service to which the car is assigned. Operating conditions, geographical locations and requirements of the service must govern the need for, and the application of this accessory.

In general, there are two types, sealed beam, and bulb and reflector, which through use have proved satisfactory. Either type will provide 35,000 beam candlepower or more.

Manufacturers now provide two types of accessories for use with the sealed beam headlight. Each type provides for a generator driven by the motor car engine. On one type a storage battery is required and on the other type no battery is needed. Both systems use an SAE No. 4012 sealed beam assembly. The battery type will provide lights while the car engine is not operating, but in the no-battery generator system the engine must be operating at an rpm. equivalent to a car speed of 10 mph.

The bulb and reflector type, of which there are several, is a portable combination hand and headlight using four No. 6 dry cells and a prefocused bulb. Accessories are available for converting the lens from a searchlight to a flood light and for holding the lamp to a flat surface. This type has one advantage of portability.

Report on Assignment 4

Power Ballasting Machines

F. H. Rothe (chairman, subcommittee), R. E. Buss, C. L. Fero, A. J. Flanagan, C. H. R. Howe, A. A. Keever, W. B. Lee, A. J. Neff, G. M. Strachan, S. E. Tracy.

This report is submitted as information with the recommendation that the subject be continued.

The last previous report of your committee on power ballasting machines appeared in the Proceedings, Vol. 45, 1944, page 100. The machine described had various deficiencies which made it difficult for an inexperienced crew to accomplish good work with it, and considerable perseverance was required to learn to use it successfully. Due to the lack of knowledge and experience in handling of the machine, some unsatisfactory work was done with it.

When first observed in operation by track maintenance men, the most frequent comment was: "Why doesn't the machine tamp on both sides of the same tie simultaneously instead of tamping between two ties, and kicking them around?" This objection was noted by the manufacturers, who set about the development of a machine that would tamp the way that track maintenance men thought that it should.

The first machine of the new type was put in service on the New York Central Railroad in 1946. During that season, this one machine tamped more than 70 miles of

high speed track. It was reported that this work was done at less expense than would have been incurred in the application of any other means under similar conditions of track, ballast and traffic. The riding and staying qualities of the track tamped were equal to or better than on track tamped by any other method.

Because it tamps on both sides of the tie simultaneously, the 1946 model has a tendency to restore slewed ties to their proper position at right angles to the rail. The tamping bars contact the ballast with a 20-in. opening between them. They are accurately directed from this point to just below the lower edge of the tie. This path is adjustable to compensate for different heights of rail and thicknesses of ties. It was found in operation that ties which were as much as one inch below the bottom of the rail could be brought to a firm bearing against the rail with two blows of the tamping head, without the use of bars or other means of raising them. From four to six blows are usually required to tamp a tie properly.

The 1946 model ballaster is an on track machine, raises the tamping head by means of lifting poles on a roller chain and strikes the same number of blows per minute as the former model.

The 1946 model, in addition to tamping both sides of the tie simultaneously, is designed to increase the force of the tamping blow about 90 percent. It also has pneumatic control of the operating mechanism which reduces the rate of fatigue of the operator, and pneumatic brakes and pneumatic jacks for raising the machine so that take-off rails may be placed under the power operated take-off wheels quickly.

With the former model the maximum speed of tamping in stone ballast was 250 ft. per hour; with the 1946 model it is possible to tamp stone ballast at an average speed of 380 ft. per hour. The maximum speed of tamping stone ballast with the 1946 model is almost 500 ft. per hour.

The manufacturer of electric vibratory tampers has brought out a ballasting machine this year which embraces an electric generating set mounted on a car with eight of the vibratory tampers mounted on a suitable frame which the operator can manipulate through hydraulic control, so that one man tamps a tie with one setting of the carrying car. To date your committee has not gathered sufficient information on the performance of this machine to go into detail concerning the speed or quality of tamping. It is believed the machine deserves consideration, and it may be possible to furnish more detailed information later.

The high cost of labor and small margin of return in railroad operation make necessary the greatest possible economy in the maintenance of tracks suitable for present high speed operation. In attempting to meet this need consideration should be given to more economical tamping of ties.

Report on Assignment 5

Snow Removal Equipment

A. W. Munt (chairman, subcommittee), W. R. Bjorklund, W. M. Dunn, C. L. Fero, A. J. Flanagan, Francis Martin, R. A. Morrison, E. H. Ness, G. M. Strachan, F. F. Zavatkay.

This is a final report presented as information.

The first report was presented last year and appears in the Proceedings, Vol. 48, 1947, pages 344–357.

Rotary Snowplow

Rotary snowplows have been in use by a number of railroads for many years, there being many types and sizes available. Some are railroad constructed while others are built by a manufacturer. Mainly these are divided into two types, the screw or auger blade type similar to that shown in Fig. 9,* and the rotary blade type similar to that shown in Fig. 10.

The screw type plow consists of a car similar to a caboose, on the front end of which is mounted a steel auger driven by an independent steam boiler and engine which are mounted in the car. The unit is propelled by a locomotive pushing it. As the machine is moved forward into the snow the auger is set in motion picking up the snow and casting it up through an opening over the top of the blades and out over the snowbank. This type of plow will clear snow for a width of approximately 9 ft.

The rotary blade type plow operates on the same principle as the screw type except that it is equipped with cutting blades similar to a propeller and clears snow for a width of approximately 10 ft.

Rotary snowplows are used mainly for clearing snow drifts that are too deep and compacted for ordinary railroad snowplows to handle. They are operated at a speed of from 2 to 3 mph., depending on the depth and density of snow.

The rotary blade type plow is more generally used on most railroads at present and is rapidly replacing the older screw type plow. The rotary blade type will handle deeper snow, throw it farther and cut a greater width. Three men are generally required to operate rotary plows. One man fires the boiler and two men occupy the operator's cab and operate the controls. When used for opening snow cuts the machine will replace up to 150 men with hand shovels.

Railroad Flangers

Railroad flangers are standard equipment for handling snow on practically every railroad concerned. Usually these are railroad constructed and are similar to that shown in Fig. 11.

The unit consists of a caboose type car which is equipped with metal scoop type blades mounted under the center of the car. The blades on the older types are raised and lowered manually by a lever inside the cab while the blades on the newer types are operated by air and controlled by an air valve located in the operator's cab. The air required to operate the blades is supplied from the train line to air reservoirs mounted in the flanger.

Railroad flangers are used mainly where snow is not too deep over the rails and to provide flangeways for the wheels so as to increase adhesion of locomotives and reduce resistance to car wheels, also to guard against freezing of snow which might follow sleet or cold rain.

Flangers are usually attached to rear of passenger or fast freight trains and operated at a speed of 30 to 40 mph. A fairly fast operating speed is required so that the snow will be thrown as far as possible as it is scooped up by the blades. At 35 mph. the snow can be thrown about 40 ft. outward. When operating the blades are usually lowered to cut about 2 in. below top of rail. Two men are usually required to operate and control the flanger.

* Figs. 1 to 8, incl., appeared in the first report.

Fig. 9.—Screw or Auger Blade Type of Plow.

Fig. 10.—A Rotary Blade Plow in Action.

Fig. 11.—A Railroad Flanger.

Fig. 12.—Using Ditchers in Snow Removal.

Crane Used in Snow Service

Many types and sizes of cranes are available. Generally three types are used for snow handling; the crawler off-track type, the industrial on-track type and the ditcher or shovel type similar to that shown in Fig. 12. While these machines were originally designed for earth and coal handling purposes they can be used to good advantage for handling snow and their use for this work will affect substantial economies.

Crawler type cranes being off-track machines are generally used for loading snow into cars in terminal yards where there is sufficient room to crawl along between or adjacent to yard tracks without interfering with switching movements. They are also used for loading snow into trucks and are often used for widening snow cuts. When used for cut widening work the machine is usually mounted on and operates from a flat car pushed by a locomotive. A ½ to ¾-yd. crawler crane will also travel over a train of flat cars and load snow on to the cars as it moves from one car to another. This eliminates frequent switching of cars. Generally a ½ to ¾-yd. machine equipped with a 1½ to 2-yd. light weight snow bucket and a 35 to 40-ft. boom is used for snow handling. The use of a light weight bucket increases the loading capacity of the crane and results in more economical handling of snow.

Locomotive or industrial on-track type cranes are generally used for loading snow into cars in terminal yards where there is not sufficient room between tracks to operate a crawler machine. The practice on most roads is to first windrow the snow with a spreader, and then operate the crane down a track picking up the windrowed snow and loading it into open top cars placed on an adjacent track which are switched out by a locomotive. This type of crane is sometimes used for loading one or two cars of snow at a time, switching and unloading them without the use of a switch engine. Generally a machine of ½-cu. yd. capacity equipped with a 1½-yd. light weight snow bucket is used for handling snow. This type of crane should have a short tail swing so that when loading cars it will not foul too much adjacent track and interfere with train movements.

The ditcher type unit is generally used for opening up and widening snow cuts where snow is too heavy for snowplows to handle or when a rotary plow is not available. It is also used extensively for widening snow cuts to provide additional clearance for the passage of trains after the cuts have been opened up by a snowplow or rotary plow or where snowbanks have been compacted by the operation of snowplows.

Generally ditcher shovels are equipped with a dipper of approximately ½-cu. yd. capacity which is rather small for snow handling. To increase the capacity of the machine a 1½-yd. light weight snow bucket is generally used. Ditchers are mounted on flat cars and can either load snow on to cars or cast it up over the bank of a cut.

Of the three types of cranes used for snow handling the crawler off-track unit is generally the most satisfactory. It has greater flexibility inasmuch as it can work on or off cars, and due to this feature greater economies are possible with this machine than with other types when handling snow; however, any of these machines when used for snow handling will replace 50 to 100 men with hand shovels.

Small Tractor Rotary Type Snowplow

Only one small rotary snowplow which is shown in Fig. 13 is presently available. This unit is a fairly recent development and only a few railroads are using it at present.

The rotary type snowplow consists of a small self-propelled 2-wheeled pneumatic-tired tractor on the front end of which is mounted a small propeller equipped with a number of cutting blades which revolve at high speed. It is powered with a 7½-hp. air-cooled gasoline engine which propels the unit and drives the propeller. As the machine

Fig. 13.—A Small Hand-Guided Rotary Plow.

travels forward the propeller cuts and picks up the snow, throwing it up through an adjustable discharge chute mounted above and to one side of the propeller. Under normal conditions it will blow snow out through the chute for a distance of 10 to 15 ft. The machine is used mainly for clearing light snow from station platforms, sidewalks and driveways, where it is desired to throw the snow over a low fence or railing or where blade plows cannot be used to good advantage. Generally the machine is not recommended for removing snow more than 6 to 8 in. deep. In deeper snow the machine, due to its comparatively light weight and small tires, does not develop sufficient traction to propel the unit; also in deep compacted snow too much resistance is encountered for the propeller housing to push through. To obtain maximum traction, the tires should be equipped with chains to decrease wheel slippage. The unit can only be operated in a forward direction and is handled by a man walking behind who controls the motor and steers the machine.

As yet the small rotary type snowplow has not proved to be entirely satisfactory for railroad use. Some roads report that the engine on the unit has insufficient power to maintain a constant propeller speed to throw the snow very far; also the propeller housing wings are not properly designed to reduce the resistance of the snow as the machine is pushed through it. As a result, frequent wheel slippage occurs and the machine stalls, particularly in compacted snow; however, regardless of minor difficulties experi-

enced with the operation of the smaller unit it will do the work of five to six men with hand shovels if the snow is not too deep. A similar but more powerful machine has very recently been made available which will handle 12 to 14 in. of heavy snow and throw it 20 to 25 ft.

Air Compressor For Blowing Snow

Various types and sizes of air compressors are available either in off-track or on-track machines. While air compressors were built primarily for operating earth, concrete and paint spraying tools they are used to good advantage for snow handling on a number of railroads.

Air compressors are used mainly for blowing snow from switches in yard tracks. They may be operated singly or in batteries of 3 or 4 units, depending on the number of switches to be cleaned and the density and depth of snow to be handled. Generally a group of machines is located at a central point in the yard and sufficient air lines are extended out from the machines to reach as many switches as possible. When a snowstorm occurs the machines are placed in operation and sufficient men are put to work to operate the air hoses and blow the snow out of the switches. One man equipped with an air hose can clean as many switches as five or six men equipped with hand shovels and brooms and clean them better.

The method of cleaning switches by air is generally recommended for use in yards where switches are not too closely grouped and there is sufficient room between tracks to accommodate the snow blown out of the switches. If sufficient space is not available the snow is likely to be blown out of one switch into another switch on an adjacent track, particularly where there are ladder tracks and double slip switches power operated.

Various sizes of air compressors may be used for snow handling but generally units ranging in capacity from 160 cu. ft. to 315 cu. ft. of air are used for the most efficient operation. When used for this work a 3-ft. length of ¾-in. pipe is fastened to the end of the air hose. Its free end is fitted with a plug with an inside diameter of ⅛ in., making the pipe virtually a blow gun through which compressed air is forced at high velocity to break up and blow the snow away.

Report on Assignment 6

Power Cribbing Machines

A. A. Keever (chairman, subcommittee), F. L. Etchison, A. J. Flanagan, C. H. R. Howe, E. C. Jackson, W. B. Lee, Francis Martin, R. A. Morrison, C. H. Ordas, T. M. Pittman, F. H. Rothe, A. H. Whisler.

This report is presented as information with the recommendation that the subject be continued.

Various types of machines have been developed for cleaning cribs. One type is a scoop or bucket which is drawn through the crib by a winch or other power appliance, collecting material in the crib which is then dumped on the shoulder. Usually, the material in the crib must be loosened with picks or a rooter before the scoop will perform satisfactorily.

An on-track machine was recently developed for excavating ballast from tie cribs and depositing this material beyond the ends of the ties by a pivoted digger boom equipped with an endless roller chain. The truck frame supports a four-wheel carriage which in turn supports the power unit and the digging and excavating mechanism.

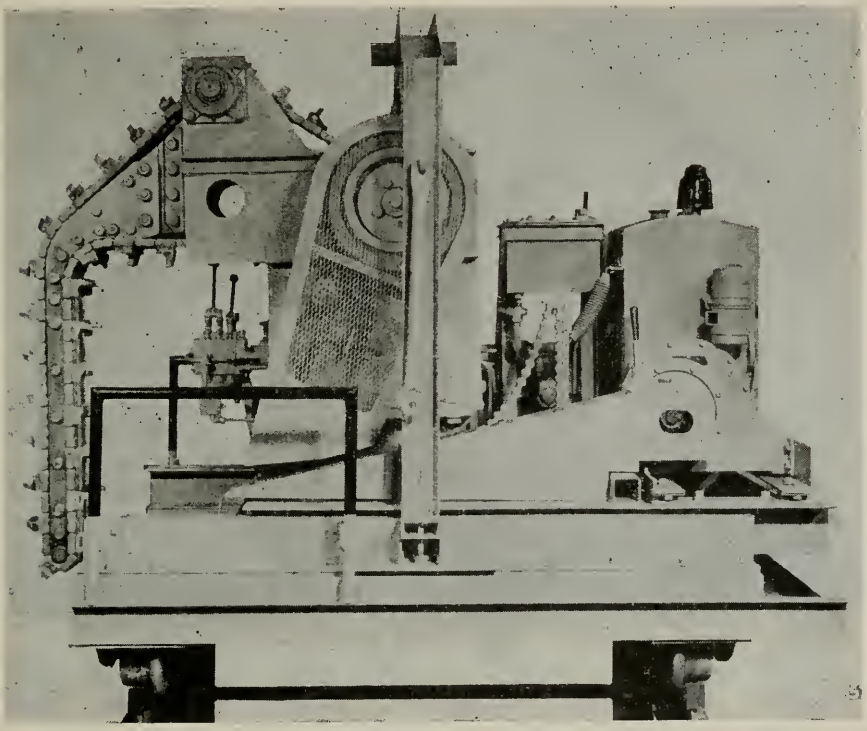

Fig. 1.—Showing Excavating Chain with Digger Flights.

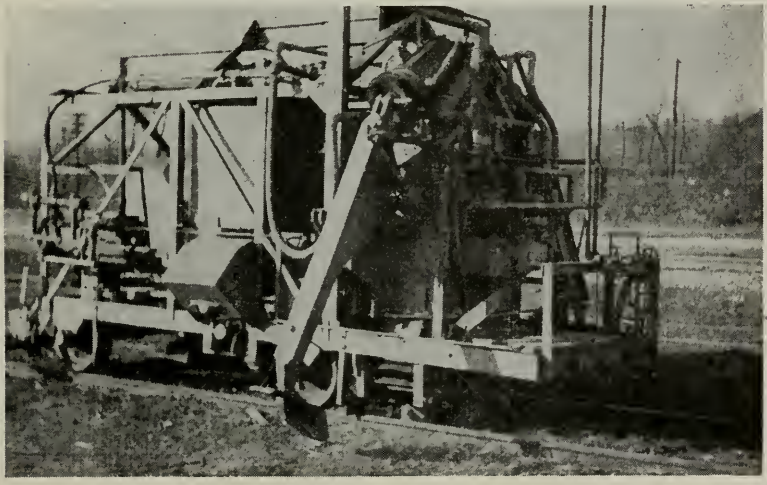

Fig. 2.—This Machine Employs Hydraulic Rams.

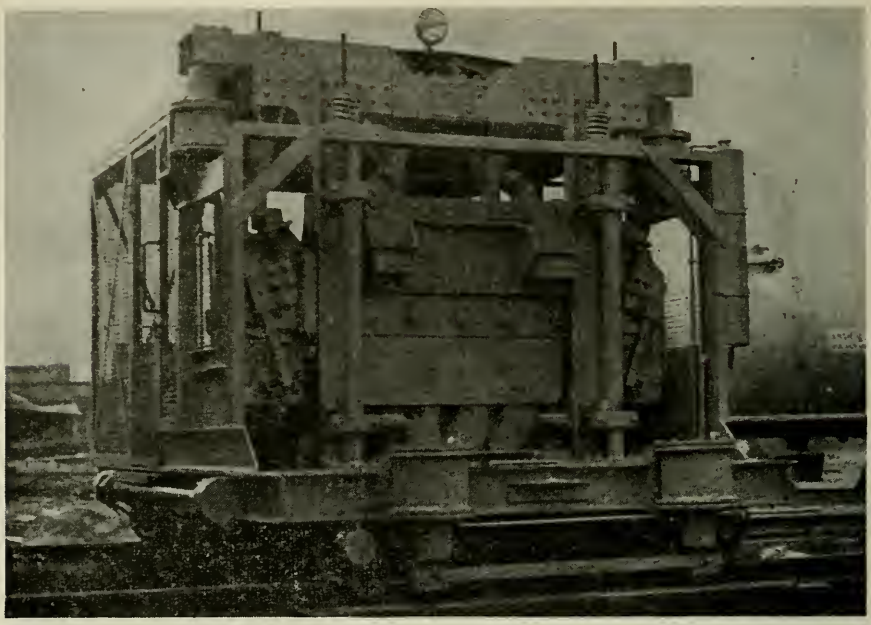

Fig. 3.—Machine with Digger Bars Mounted on a Crosshead.

Fig. 4.—One of the Digger Bars.

The excavator boom is in the form of a "U." When in the extreme lowered position, the U is on its side with the open ends extending towards the center of the track. At the end of one leg of the U is the pivot point. The other end is the nose of the digger.

The excavating means travels around this U form. It consists of two strands of specially constructed roller chain to which digger flights are attached. The roller chains are caused to travel in a closed-circuit path by means of a series of sprockets, rollers and chain guides. The excavating chain and digger flights travel the path in such a manner that at the top, of the top of the digger boom, the flights more inwardly toward the center of the track and at the bottom, outwardly or away from the track center. By reason of the rotational movement of the digger boom nose, when it is lowered into the crib, the nose of the digger boom first contacts the crib ballast at a point just outside the rail base. As soon as the initial entry hole is dug, the digger boom proceeds to move downwardly and inwardly, until at the maximum downward position the nose is well under the base of the rail and the body of the boom is level with the bottom of the ties, the ballast being thrown outwardly beyond the tie ends.

Hydraulic control valves are conveniently located on the carriage frame to enable the operator to manipulate the machine. Power for operating the digger mechanism and the hydraulic pump is provided by a four-cylinder gasoline engine mounted on the rearward side of the transverse carriage. A hydraulic set-off device is provided to remove the machine from the track. The unit is not self-propelled and must be handled to and from the job by motor car. An operator and an assistant are required on the machine. The weight of machine without extra digging chains, hydraulic set-off and spare parts is about 4500 lb. (See Fig. 1.)

A crib cleaning machine is now being built which works on track and takes the ballast out of the crib by pushing the ballast from the end of tie to a position between the rails by means of hydraulically operated rams, this material then being picked up by a bucket digging conveyor and delivered to a vibrating screen for separation. The ballast is returned to the crib and the dirt is collected by a swing conveyor at the rear of the machine and delivered to either side of the track or into a small car directly back of the machine. Ballast which falls on top of ties is brushed into the cribs as the machine proceeds. The machine is propelled by an hydraulic motor at a speed of 15 mph. in either direction. This motor also spots the machine over the crib. Rams and buckets are 9 in. wide. Set-off wheels are provided for removing the machine from the track. (See Fig. 2.)

Another on-track crib cleaning machine employs a heavy crosshead, extending across the track the full length of the crib. Transversely acting digger bars are mounted on this crosshead. The crosshead is raised by a continuous chain drive, and falls freely after being released at the top of the lift. There are eight digger bars mounted on the crosshead, four working out each way from the center of the track, depositing ballast on each side of the track beyond the ends of the ties. The mounting of the digger bars is such that there is a force transverse to the track tending to loosen the material being cribbed. After these digger teeth work down to the base of the tie, there is a cam controlled action which forces the digger teeth outward from the center of track. The digger bars are equipped with renewable digger teeth of an abrasion-resisting material. The machine is equipped with power-operated transverse set-off wheels and a power lift, so it can be removed from the track in 3 to 5 min. Air controls are used in operation. This unit is self-propelled and has a traveling speed of about 25 mph. (See Fig. 3 and Fig. 4.)

Report on Assignment 7

Power Spike Machines

F. L. Etchison (chairman, subcommittee), W. M. Dunn, E. B. Harris, A. A. Keever, Jack Largent, F. H. McKenney, A. W. Munt, A. J. Neff, John O'Farrell, F. H. Rothe, J. R. Rushmer, M. C. Taylor, G. R. Westcott.

This report is presented as information with the recommendation that the subject be discontinued.

Of power spike machines which have been developed, only two types have proved satisfactory, the pneumatic and mechanical.

The Pneumatic Spike Driver

The pneumatic machine was developed from the paving breaker and tie tamper, using compressed air from available sources. The commonly used air compressor was pressed into service as a power plant. This plant varies from the small mobile compressor to the large self propelled units, the first mentioned operating one spike driver, the latter up to 12. The users commonly assemble the necessary outfits to suit their needs. The most commonly used outfits are compressors mounted on push cars with overhead pipes or similar devices to carry the air hose out in front, or to the rear, or in both directions, so as to keep clear of the ground. In some instances operator's fatigue has been reduced by suspending the drivers from the frame, using springs or hangers. Other outfits used are the mobile air compressor pushed along the roadbed, and the self moving units, which likewise move along the roadbed or track, depending on whether work is being done under traffic or on a dead track.

The small compressors, such as four-tool tie tamper units, can only operate one spike driver effectively and efficiently. The larger the compressor the greater the number of spike driver units it can operate. The length of the hose hook-ups between the compressor and the spike driver varies from 15 to 50 ft., as required by the operating conditions.

Being developed mainly from a paving breaker, the pneumatic spike driver, if not suspended from an extension rig of the outfit, must be carried or slid along the rail. The weight of the unit without hose is from 60 to 80 lb. The unit has a recessed hammer-block construction which prevents the tool from slipping from the head of the spike. The average time to drive a spike is from 3½ sec. in soft woods to 6 sec. in the hardest oak.

For efficient operation the air pressure must be kept uniform and at capacity. The spikes must be set straight and firm, with proper supervision to see that they are not overdriven to damage either the rail or the spike heads. It is necessary that a crew of from one man to three men be used to set the spikes for each pneumatic spike machine.

The pneumatic power spike machines have the following advantages over hand work: Better holding power of the spikes because of even and rapid driving, and lower cost per spike driven.

Gasoline Powered Spike Drivers

There are two self contained gasoline powered spike drivers. These machines were developed as paving breakers, but by changing the nose housing casting they can be converted to a spike driver. The machines weigh approximately 97 lb. without the tool, one has a single cylinder, air-cooled engine with two pistons. One piston actuates the

flywheel magneto and cooling fan which is at the top of the unit. The other is a free piston and is actuated by explosive pressure, striking directly on the shank of the tool at 2000 blows per min. This striking piston is returned by low gas pressure to the "up" position for the next explosion. A hand throttle controls the power of the tool so that when idling the striking piston does not operate, making it easy to spot on the spike. This machine drives spikes at the rate of one spike per 3 sec. in soft ties to one spike per 5½ sec. in hardwood. This is a one-man machine, but due to its weight it is necessary to relieve the operator at regular intervals or counterbalance the machine. The other machine is similar except that it has a spring-returned block piston. One advantage claimed for this type of machine is that where a group is being used, the failure of any one machine slows up the work underway, but does not stop it.

Another recently developed spike driver is a self-contained unit, which weighs approximately 865 lb. It is mounted on a carriage that rolls along the rails. A full revolving frame mounted on the carriage contains all of the driving mechanism. The revolving frame is a balanced beam with a 6-hp., 4-cycle, single-cylinder air-cooled engine unit for the power plant on one end, and a revolving mechanical hammer on the other end. The engine drives the hammer by means of three V-belts.

The spike driving mechanism consists of a rotating steel spider, in which a revolving hammer is mounted. This hammer weighs approximately 28 lb. and as it revolves at a speed of 975 rpm., the force of the blow it delivers is approximately 4000 lb., which is effective.

Directly under the revolving hammer is an anvil guide, which contains an anvil approximately 10 in. long, which receives the blow from the revolving hammer and delivers it to the top of the spike. This anvil has a limited vertical motion in the guide so that normally it hangs down out of the path of the revolving hammer. The lower end of the anvil guide extends below the lower or striking end of the anvil, thus forming a circular wall to keep the head of the spike directly under the anvil. When the lower end of the anvil is placed on the head of the spike for driving, it pushes the anvil up into the path of the revolving hammer, resulting in quick driving of the spike. When the spike is completely driven, the revolving head is raised, the anvil falls away from the path of the revolving hammer which rotates freely with a minimum consumption of power. The movement of the anvil is adjustable so as to compensate for wear.

An adjustable set screw attached to the frame is set to come in contact with the rail head and prevents lowering the driver below the base of the rail so that when the spike is fully driven, the head just comes in contact with rail base. This is adjustable to any rail height to prevent over driving or damage to the rail.

A tray is carried on each side of the revolving frame in convenient reach, in which spikes are placed for driving. They hold approximately a half keg.

The crew consists of an operator who pushes the machine along the track and two men with spike holders, setting spikes. The spike holders weigh approximately 6 lbs. and the spike is held against a hardened steel guide by a spring clip. This tool has a handle 3½ ft. long which enables the spike to be placed alongside the rail for driving without the necessity of stooping over. The men with spike holders place the spike in position for driving, the operator moves the anvil guide directly over the spike and then sets the machine down on the spike head, the pressure on the anvil raises it up to the revolving hammer, which strikes the anvil, starting the spike. The spike holder is pulled away and the man using it gets another spike from the tray and places it in the tool for the next operation. In the meantime, the operator has driven the spike, moved the machine ahead or swung it over, and it is set on the spike (usually on the opposite side of the rail) held by the other man.

Because this machine is full revolving, which allows it to be operated in either direction, on either rail, it drives anchor spikes as easily as holding spikes. Spikes may be driven at switches or frogs as much as two feet from the gage line of the track on which the machine is resting. However, operators should be cautioned when doing this, as the adjustable stop screw misses the rail head when the machine is swung out, with the result that the operator can, if he continues to bear down on the machine, keep on driving the spike after it is in contact with the metal plate. The spike, instead of absorbing the blow in movement, transfers the force back to the anvil, resulting in chipped or cracked anvils. If desired, stop screws can be attached which will bear on tie plate or other surfaces, thus affording protection against this possible damage.

Unless spikes are set right the machine will not drive them. Spikes are driven vertically, and if the spike is not held in the vertical position it will be kinked. Later these kinked spikes are pulled and redriven by hand. From 700 to 800 spikes can be driven per hour by each machine used.

The advantages claimed for this machine are:

It only drives vertical spikes
Does not damage rail
Can be removed from track by six men or a crane
Releases men for work elsewhere
Expedites rail laying and improves the quality of the work.

Report on Assignment 9

Flame Cleaning Equipment for Steel Bridges and Buildings

T. M. Pittman (chairman, subcommittee), E. L. Anderson, C. M. Angel, R. E. Berggren, F. L. Etchison, C. H. R. Howe, R. M. Leeds, Francis Martin, C. E. Morgan, S. E. Tracy, E. G. Wall.

This is a final report submitted as information.

The flame cleaning of steel requires a quick and intense heat that will produce a steep thermal gradient between the scale and the parent metal which will cause the scale and other surface material to expand rapidly and separate from the parent metal. A slow heat will cause a fusion instead of a separation. The oxyacetylene flame has been found best adapted for this purpose and is generally used in the operation. Fig. 1 shows a typical gas tank hook up. Various types and sizes of descaling tips are available, but those best adapted are flat and vary from 2 to 6 in. in length. The longer tips are used on large flat surfaces to be cleaned, while the shorter tips are used on smaller members and in extremely close places, the 4-in. tip being more generally used in cleaning. Fig. 2 shows a torch with a blow type tip. These cleaning tips have ports, No. 75 drill size, and are 0.002 in. in diameter. Even with such small port holes the velocity is so high that the flames are over ¼ in. long. It is important that the flame tips be kept at a uniform distance from the surface to be cleaned, and the long tips are provided with skids made of extremely hard and heat resistant alloys such as Stellite. For best results, flame is directed to the surface to be cleaned at an angle of about 60 deg. The tips may be applied to standard welding torches or an extension blow pipe.

Following is the equipment required for a two-torch operation, and necessary reserves:

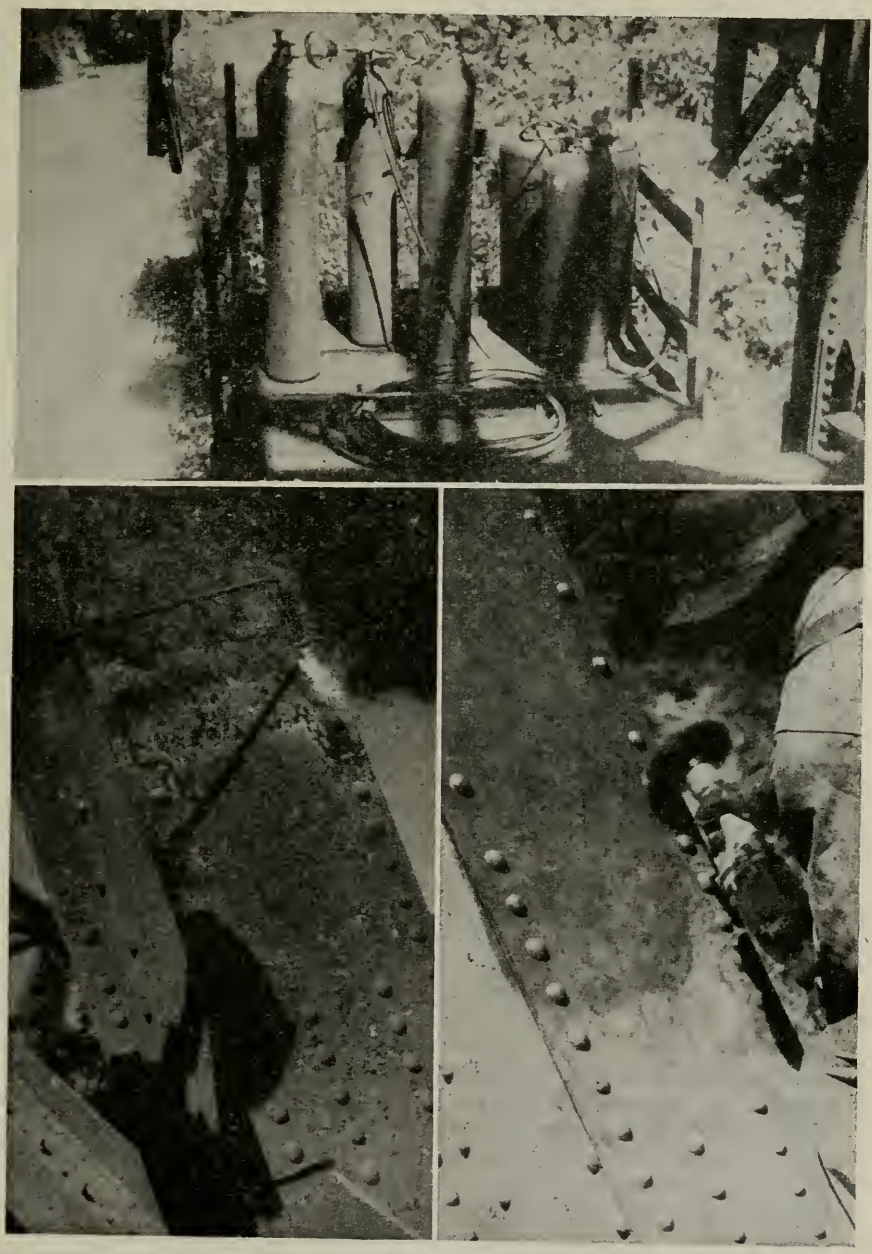

Fig. 1 (Top).—Tanks Set Up for Torch Cleaning; Fig. 2 (Left).—Torch Using a Blow Type Tip for Cleaning; Fig. 3 (Right).—Brush Cleaning Following the Torch; Bright Rivet Heads Indicate Thoroughness of Cleaning.

2—5-Cylinder oxygen manifold blocks
9—Steel coils
2—3-Cylinder acetylene manifolds
5—24-In. hose connections
2—Blind glands
2—Nuts
2—150-Ft. sections of ¼-in. twin hose (with glands and nuts)
4—Hose splicers
3—Oxygen regulators
3—Acetylene regulators
3—Welding torches
4—Mixing heads
3—12-In. straight extensions
3—16-In. angular extensions
4—Round descaling tips
3—Adapters
3—18-In. straight extensions
3—Adapters
2—4-In. flat descaling tips
3—5-Way wrenches
3—Sparklighters
12—Sparklighter flints
3—Pr. coverspec goggles
6—Pr. asbestos safety gloves
2—Pr. cape type safety sleeves
2—Safety aprons
6—No. 75 drill bits

Flame cleaning and dehydration leaves the surface material that is not blown clear by the torch dry so that the remaining material can easily be removed with a power driven wire brush following the advanced operation, and painting should be followed as closely as practicable before the material completely cools and gathers moisture and rust. Fig. 3 shows the operation of a wire brush following the torch.

Flame cleaning compared with sand blasting is more economical particularly for jobs on the line of road because the apparatus can be handled more conveniently to and from the job than the heavy compressors and sand required for the blasting work. Also, it eliminates the undesirable fogging of dust from the sand operation on to painted areas and over clean sections that require reblowing and cleaning in advance of painting.

In cleaning buildings of frame or other construction where heavy coats of old paint are to be removed, it has been found practical to use butane or propane gas, contained in approved steel cylinders, and used through large flame hand torches similar to those commonly used in melting snow and ice or burning grass and weeds around tracks. These torches are connected with the gas cylinders by means of hose and consist of the proper size of metal tube or blow-pipe about 4-ft. long, with the proper size orifice and control valve and burner head to contain and guide the flame. Care must be taken to guard against fire originating from the flame or damage to the surface being cleaned. Any cracks or spaces that might develop fire from the flame should be fully caulked or puttied before the flame is used over the surface. Wide blade scrapers are used immediately following the flame in order to remove the old paint remaining on the surface.

Report on Assignment 10

Machinery and Equipment for Stabilizing Roadbed

R. E. Buss (chairman, subcommittee), R. E. Berggren, W. R. Bjorklund, W. M. Dunn, C. W. Engle, E. B. Harris, E. C. Jackson, W. B. Lee, F. H. McKenney, A. J. Neff, P. G. Petri, J. R. Rushmer, J. L. Starkie, M. C. Taylor, E. G. Wall, G. R. Westcott.

This is a final report submitted as information.

The assignment, Machinery and equipment for stabilizing roadbed, was reported by your committee in the Proceedings, Vol. 48, 1947, page 363, and because no additional equipment nor improvement in existing machinery or equipment for this class of work has been developed since the last report, continued study of the subject appears unnecessary at this time.

Among methods of roadbed stabilization not covered in previous reports are the driving of poles or piling at the ends of the ties, and the driving of spuds into unstable roadbed and withdrawing them in order to back-fill with sand so as to introduce greater friction and stability in the subgrade. Within recent years, a great deal of work has been done on both embankments and cuts by the driving of ties or poles at the ends of the cross ties. This method of treating unstable track is not a new method by any means, as some railroads have been using it for the past 30 years with gratifying success.

One machine used in this work is a railborne self-motivating pile driver, as shown in Fig. 1. The leads vary in height from 8 to 23 ft. The power plant is a gasoline engine. The hammer weighs 3000 lb. and strikes 18 blows per minute. Under some conditions this rate permits driving as many as three 8-ft. poles per minute. Under normal driving conditions the output of one machine will average around 700 to 800 8-ft. poles in each working day. The transmission of power to the drum, which raises the hammer by means of a ¾-in. wire rope, is normally accomplished through a friction clutch. However, machines are being equipped with hydraulic clutches. These machines are equipped with a set-off arrangement which permits them to clear the track under their own power in from 1 to 5 min. depending on the distance it is necessary to travel.

As a general rule it is the practice to operate two machines, driving on opposite sides of the track simultaneously as shown in Fig. 1. Each machine is complemented by a crew of four men, including an operator.

Off-track skid type equipment is also used for this type of work and is especially advantageous in obtaining high production on railroads of high speed and dense traffic operations. Fig. 2 illustrates this method. The most practical equipment of this type includes leads 20 to 32 ft. long, a 3000-lb. drop hammer and a 50-hp. gasoline engine for power.

When driving piling at the ends of track ties, the track can be completely cleared for traffic within 3 min. of completion of the driving operation; and the machine can be back at work and driving a pile within 60 sec. of the passing of the train. The equipment is usually worked under flag protection, and quite often with a stop order and short flag; but in either event, with no interference with traffic or delay to trains.

This equipment is moved between locations, usually not over five to ten miles, loaded on a heavy duty specially designed push car and pulled by a heavy duty motor car. These moves are made under flag protection, also, and the entire load can be removed and track cleared within 10 min.

For the driving of shorter timbers, 8 and 10 ft. in length, similarly designed but smaller equipment is used, with 2500-lb. hammers and the same power plant. This

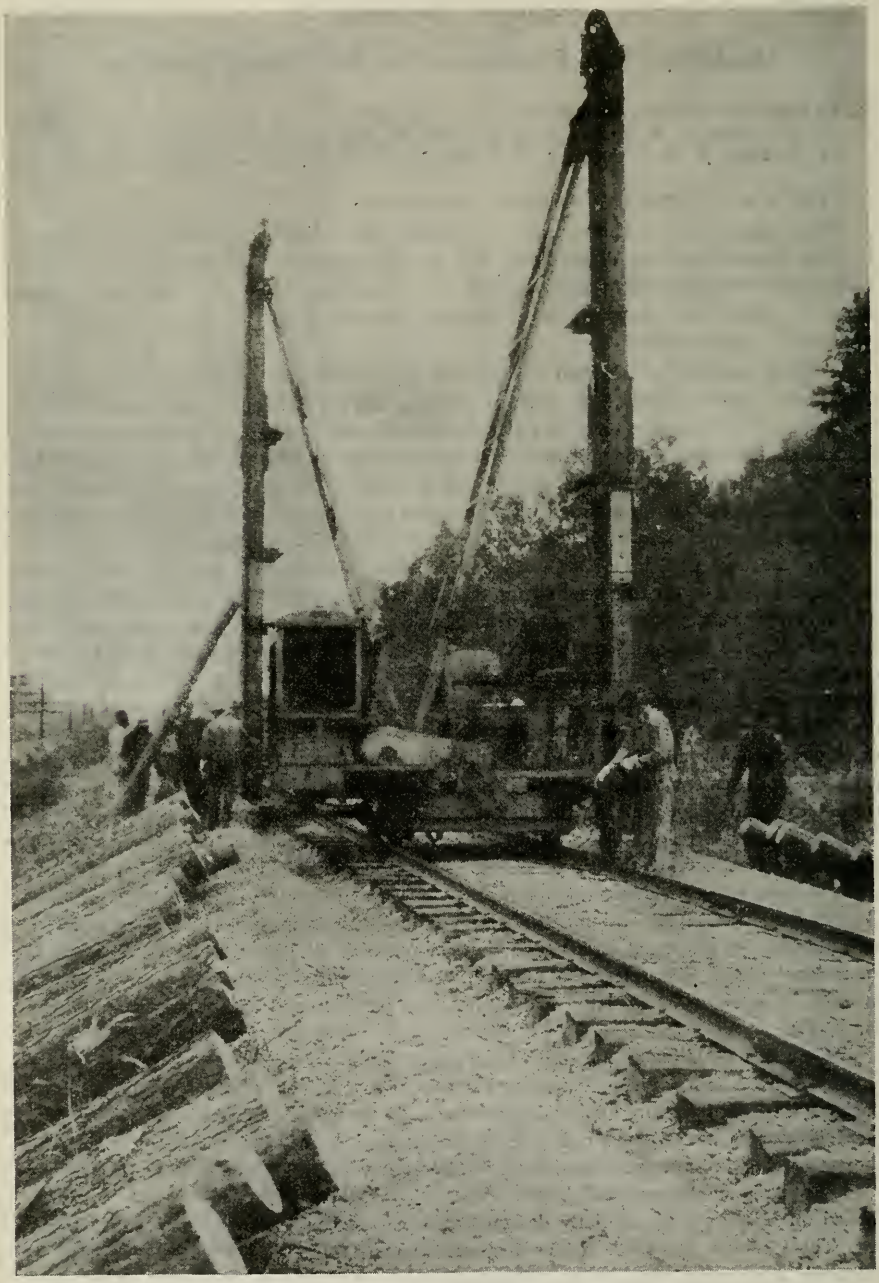

Fig. 1.—Driving Poles with 3000-lb. Drop Hammers.

Fig. 2.—Driving Piles with an Off-Track Skid Driver.

Fig. 3.—Driving a Spud with a Steam Pile Driver.

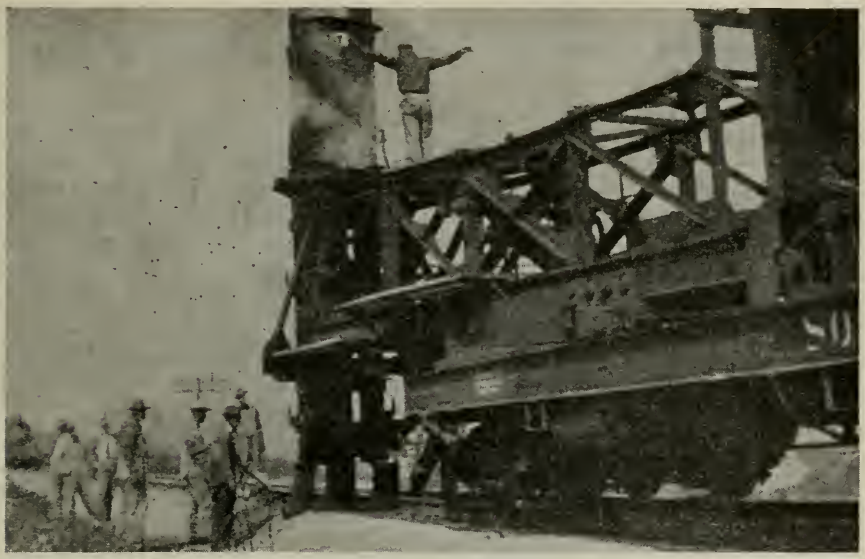

Fig. 4.—Pulling the Spud.

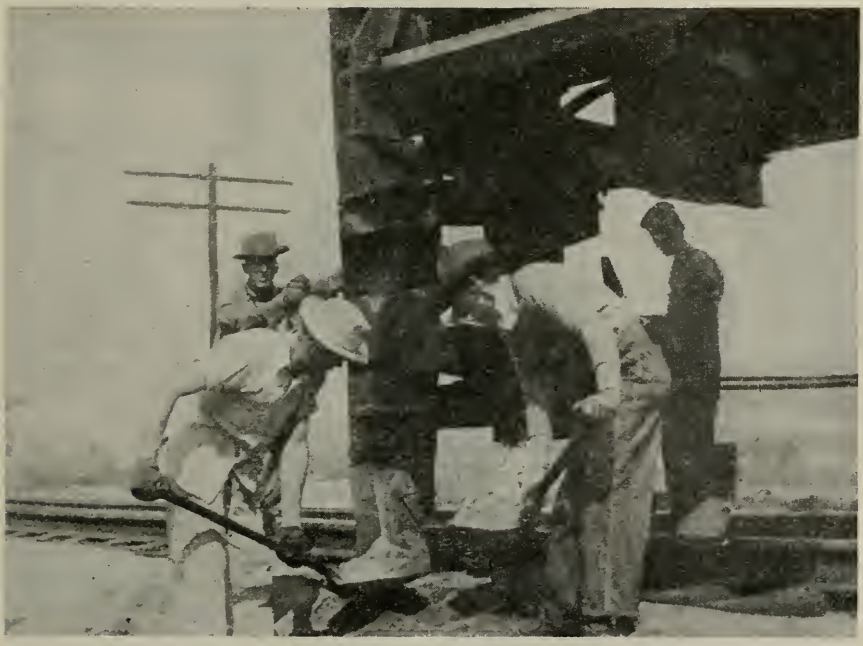

Fig. 5.—Backfilling the Hole Left by the Spud with Sand.

equipment is designed for operation either on or off the rails, or for operation mounted on track cars, which are removable in the same manner as a rail-laying machine—with two sets of wheels set at 90 deg.

Standard on-track pile drivers with steam hammers in tandem are usually employed in driving spuds to introduce sand into the roadbed, and stabilization depends on the proper percentage of sand (usually from 15 to 20 percent) being introduced at various locations, and the pattern for driving must be worked out for these results. Fig. 3 shows pile driving equipment driving spuds for introducing sand in soft roadbed. Fig. 4 illustrates the pulling of the spud by means of the driver, with movable blocks under each side of the leads to afford better support. Fig. 5 shows men backfilling with sand the hole left by the spud.

The driving of spuds for this type of stabilization can be done more economical'y by an off-track driver where roadbed widths are such that the equipment can be placed to handle the work without excessive intereference with train operation.

Report on Assignment 11

Ballast Cleaning Equipment

G. M. Strachan (chairman, subcommittee), R. E. Buss, C. W. Engle, N. W. Hutchison, R. K. Johnson, R. M. Leeds, John O'Farrell, J. R. Rushmer, J. C. Ryan, J. L. Starkie, E. G. Wall, A. H. Whisler.

This is a final report submitted as information.

The assigned subject, Ballast cleaning equipment, was last reported on by the Special Committee on Maintenance of Way Work Equqipment, Proceedings, Vol. 33, 1932, page 183. This report covered the off-track "Mole" and a large railroad-constructed on-track shoulder ballast cleaning machine.

The cleaning of shoulder ballast and intertrack space ballast of late years has been receiving considerable attention in an effort to provide better shoulder drainage and thus reduce track maintenance expense. Various types of off-track and large on-track ballast cleaning machines are now being used by many railroads, but perhaps emphasis to date is on the large on-track machines because of their greater production speeds. However, due to the investment required in the larger cleaning units the major portion of shoulder ballast cleaning in the past has been done by contracting companies using the large on-track machines, but a few railways have designed and built in their own outfits. These on-track machines usually depend on a work train engine for propelling power, and the shoulder ballast cleaning machines of an eastern and a western railroad, described below, are representative of the large company owned machines.

On-Track Shoulder Ballast Cleaning Machines

An eastern railroad for several years has been operating three shoulder ballast cleaners of its own design, constructed in company shops. (See Figs. 1 and 2.) The cleaner cars are self-propelled, and connected to each cleaner is a 30-cu. yd. air dump car to which the dirt and screenings are conveyed; and when filled the car is hauled out and dumped along the right-of-way. Two of the older cleaners are gas operated, but the newer car, which weighs 111,000 lb., is operated by a 125 hp. diesel engine, direct connected to a generator, and all individual operations are motor driven. The cleaning apparatus is mounted on one side of the car, so only a single shoulder is cleaned. These

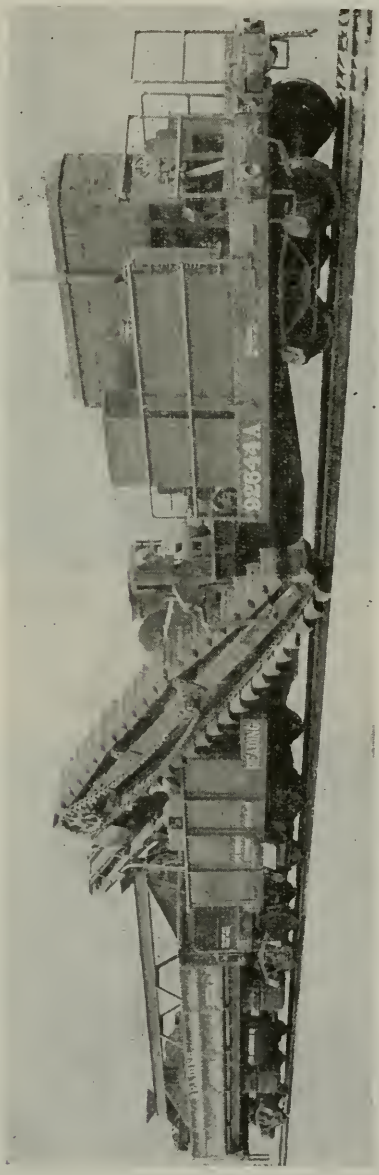

Fig. 1.—Side View, Eastern Railroad Ballast Cleaner.

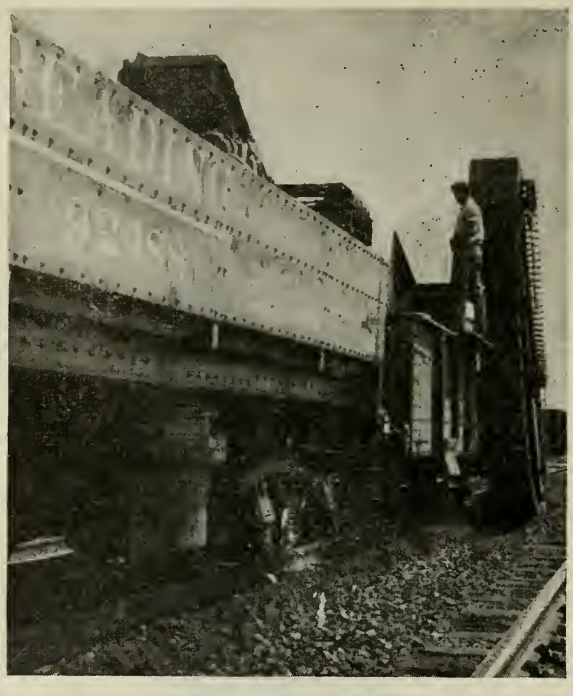

Fig. 2.—Operational View, Eastern Railroad Ballast Cleaner.

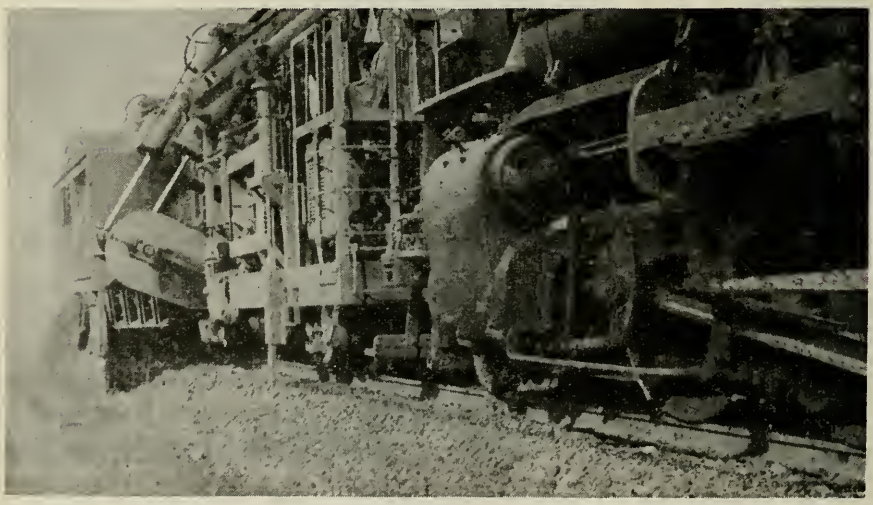

Fig. 3.—Front-Side View, Western Railroad Ballast Cleaner.

three cars are worked in a battery with one work train engine and crew for assembling in clearing for trains and other handling. The work train distributes the cleaning cars a certain distance apart and then the cars work under their own power, propelling themselves along as the cleaning is being done.

Ballast cleaning equipment consists of a bucket flight chain, containing on the newer model, approximately 42 buckets 21 in. wide by 7 in. deep, which works on a beam arrangement, raising the ballast from the shoulder and dumping it into a hopper which in turn dumps it on a screen—the clean ballast being returned to the shoulder and the dirt and screenings being conveyed to the dump car for disposal. An adjusting device governs the depth below the level that it is desired to clean. By power control the ballast elevating arm is retractable to a position inside of the car to provide normal clearance for the passage of trains on the adjacent track or when in transit. In operation, the extended cleaning arm fouls the adjacent track so that on double track of 11 to 12½-ft. centers, flagging is necessary on both tracks.

The ballast cleaning personnel consists of a foreman, 3 subforeman, 3 operators and 9 laborers. The output of the ballast cleaning cars of course depends largely on the density of traffic and whether or not the ballast shoulder is heavy enough or foul enough to require two passes. Best results, however, are secured by making two passes over a shoulder or center ditch as the first pass loosens up the ballast and aerates it, permitting it to dry out; and the second pass takes out the dirt. The cleaning speed of the electric driven unit is approximately 25 lin. ft. per min., or about 1500 shoulder ft. per hour.

Shoulder ballast cleaning machines are proving very satisfactory on this eastern railroad, which is planning to replace two older gas operated machines with two new diesel operated units.

A western railroad now has in successful operation a recently developed shoulder ballast cleaner of unusually large capacity which incorporates a new principle of design. (See Fig. 3.) This new type ballast cleaner, weighing slightly over 200,000 lb., is mounted on a specially designed all steel car of heavy construction, and in operation is drawn or pushed by a locomotive at a speed of from 2 to 2½ mph., depending on the amount and condition of the ballast in the shoulders. The major operation involved in cleaning the ballast is performed by two giant revolving wheels 12½ ft. in diameter, one on each side of the car. These wheels, powered by individual 135-hp. engines, are independently operated. Buckets in the periphery of the wheels are so designed and positioned that the ballast picked up as the wheels revolve is dumped inside the wheels and diverted to a set of grizzly screens where the material is cleaned, the good ballast being returned to the shoulder while the dirt and screenings is belted out and wasted on the side of the roadbed. By means of a set of baffle plates the returned ballast is shaped to shoulder design and no further dressing is required.

In advance of the ballast wheels, on each side of the car, are two devices by means of which the ballast is loosened to prepare it for being picked up by the elevator wheels. Side fluted frames on the forward end of cleaner, guide the full shoulder of ballast into pickup position.

When the machine is in transit, the wheel frames are folded back into the sides of the car within normal clearances; for operation they are lowered outward and downward to the elevation desired. These movements are controlled by large air and hydraulic cylinders which permit locking at any desired position.

This western railroad shoulder ballast cleaner was designed primarily for single track shoulder cleaning, however, it has been successfully used on double track although

some adjustments in ballast pickup and disposal arrangement is necessary but these changes can readily be made in a short time. In operating on double track it has been felt desirable to clear for trains on both tracks, and as a result, cleaning costs are approximately 10 to 15 percent higher on double track than on single track.

Ballast cleaning operations and personnel are under supervision of the roadmaster or an equivalent officer. The crew (exclusive of the train crew) is composed of two operators and two assistants, plus the services of a regularly assigned welder. Frequently two section laborers are included in the crew to patrol ahead of the cleaner and remove foreign objects from the ballast.

This western railroad shoulder ballast cleaning machine, working in semi-arid territory in 1946, cleaned over 720 miles of track (both shoulders) in a total of 207 actual working days, or approximately 3.5 miles per day. One shoulder cleaning usually was sufficient, but on about 10 percent of the mileage where the ballast was extremely foul, a second cleaning was necessary.

Conclusions

A first-class job of shoulder ballast cleaning is being secured by both the eastern and western railroad machines and the results to date indicate that shoulder ballast cleaning has resulted in lowered track maintenance on all tracks cleaned.

Report of Committee 17—Wood Preservation

C. S. Burt, *Chairman,*
W. P. Arnold
R. S. Belcher
P. D. Brentlinger
Walter Buehler
C. M. Burpee
G. B. Campbell
H. B. Carpenter
W. F. Clapp
L. S. Crane
R. F. Dreitzler
H. R. Duncan
T. H. Friedlin
W. H. Fulweiler
F. W. Gottschalk
F. A. Hartman
F. W. Hillman
H. L. Holderman
B. D. Howe
R. S. Hubley*
R. P. Hughes
M. F. Jaeger
A. L. Kammerer
A. J. Loom
W. R. Goodwin,
Vice-Chairman,
L. A. Olson
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J. N. Roche
Henry Schmitz
L. B. Shipley
T. H. Strate
J. E. Tiedt
Hermann von Schrenk
C. H. Wakefield

Committee

* Died June 27, 1947.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Service test records of treated wood.

   Progress report, submitted as information ..... page 179

3. Destruction by marine organisms and possible ways of prevention.

   No report.

4. Creosote-petroleum solutions.

   No report.

5. Destruction by termites and possible ways of prevention.

   No report.

6. New impregnants and procedures proposed for increasing the life and serviceability of forest products.

   No report.

7. Incising forest products.

   Progress report, submitted as information ..... page 192

8. Use of straight coal tar for tie treatment and results obtained.

   No report.

9. Review the specifications for creosote with particular respect to limitation of residue above 355 deg. C., and other revisions resulting from changes in processes of manufacture.

   Progress report, presented as information ..... page 194

AREA Bulletin 470, December 1947.

10. Development of specifications for the treatment of wood to make it fire resistant, including: (a) methods of treatment; (b) chemicals; (c) wood preservatives and amount thereof to be added to fire-resistive salts; (d) performance test methods; and (e) interpretation of test results.

No report.

11. Preliminary conditioning of forest products for treatment by artificial methods of seasoning.

Progress report, submitted as information ..... page 195

THE COMMITTEE ON WOOD PRESERVATION,
C. S. BURT, *Chairman.*

Ross Strominger Hubley

Ross Strominger Hubley, inspecting engineer of wood preservation of the Great Northern Railway at St. Paul, Minn., died June 27, 1947.

Mr. Hubley was born in Harrisburg, Pa., December 18, 1881, and received the degree of Civil Engineer from Lafayette College, Easton, Pa. He began his railroad career as instrumentman on the Pennsylvania Railroad. After a year with the Pennsylvania, he accepted a position with the Spokane & Inland Railroad, at Spokane, Wash., serving as draftsman, levelman, instrumentman, assistant engineer, and locating engineer. He remained with the Spokane & Inland four years, after which he became resident engineer of the Washington, Idaho & Montana Railroad, and a year later steel inspector and draftsman of the Spokane, Portland & Seattle Railway, becoming structural draftsman for the road two years later. From 1924 to 1926 he was in the engineering department of the Great Northern Railway, St. Paul, Minn., and in 1927 was appointed engineer of timber preservation for that road, and was inspecting engineer of wood preservation at the time of his death.

Mr. Hubley was elected to membership in this Association in October 1913. He served as a member of Committee 3—Ties, from 1928 to 1933, and as a member of Committee 17 from 1927 until his death.

He will be keenly missed by his many friends in the Association, and his loss will be deeply felt by Committee 17.

Report on Assignment 2

Service Test Records of Treated Wood

A. J. Loom (chairman, subcommittee), T. H. Friedlin, W. R. Goodwin, H. L. Holderman, R. P. Hughes, T. H. Strate.

The following report of test records of ties is submitted as information:

Atchison, Topeka & Santa Fe Railway
Kingman, Ariz.

In connection with the construction of second track in 1922 in the vicinity of Kingman, Ariz., the Santa Fe started a tie test which included approximately 35,000 ties of 8 kinds of wood and 6 preservative treatments. Ties in this test have been under main line traffic for 25 years, and it is the purpose of this report to show service life to the date of the last inspection for each kind of tie and treatment.

It was the object of this tie test when it was started in 1922, to compare various woods and treatments under similar conditions of climate, traffic and ballast, and with this in view, ties were laid in groups of 100 ties of a kind, with one or more duplications of these groups.

At the time of construction, the track was laid with 90-lb. rail on a ballast of pit-run gravel from the Hackberry, Ariz., pit, the tie plates at that time being 7½ in. by 9 in. In 1936, the 90-lb. rail was replaced by 112-lb. rail on the same ballast but with 7¾-in. by 11-in. tie plates. In 1945, the track was given an average 4-in. raise on crushed rock from Shipley, Ariz.

Statement "A" is a summary of results to January 1, 1947, average service life from each kind of wood of each treatment being shown separately, but with a summary of results from ties of all woods, separated as to treatments. Statement "A" shows not only the number of each kind laid in the test in 1922, the percent removed to 1947, and the average service life to January 1, 1947, but also shows the expected average life based on the Forest Products Laboratory curve, for each kind and group. A summary of results from each of the treatments is as follows:

Treatment	*Number Inst. 1922*	*Percent Removed to 1–1–47*	*Average Life to 1–1–47*	*Expected Average Life*
½ lb. Straight zinc chloride	2594	100.00	8.95	8.95
½ lb. Zinc chloride followed by 5 lb. petroleum	5356	82.51	17.46	20.51
½ lb. Zinc chloride followed by 5 lb. 30% creo. 70% petr.	5098	84.94	18.39	19.83
5 lb. Rueping creosote	8143	60.54	20.99	24.00
7 lb. Rueping creosote	5962	61.07	21.39	24.00
7 lb. Rueping mixture 50% creosote 50% petroleum	7725	50.83	21.87	25.81

As will be noted from the above tabulation, all of the straight zinc chloride treatment test ties are now out of track, having given approximately a nine-year service life. Zinc chloride followed by creosote-petroleum solution, or straight petroleum, is in the neighborhood of 85 percent removed from track, and when the Forest Products Laboratory curve is applied to these groups, an average expected life of approximately 20

Summary of Results to January 1, 1947 From Approximately 35,000 Test Ties in the Kingman, Arizona, Test of The Santa Fe Railway

This Tie Test Has Been in Existence Since Second Track Was Built in 1922

Statement "A"

Symbol	Kind of Wood	All 5 lb. Creosote Treatments Treatment	Number Inserted in 1922	Number Removed Jan. 1, 1947	Percent Removed Jan. 1, 1947	Average Life to Jan. 1, 1947	Expected Average Life
CRA	Hewn Texas Pine	5 lbs. Rueping Creosote	401	384	95.76	20.71	20.91*
CRB	Hewn New Mexico Pine	5 lbs. " "	380	288	75.79	21.72	22.92†
CRJ	Sawn Texas Pine Wide Ring	5 lbs. " "	194	157	80.93	20.07	20.51
CRK	Sawn Texas Pine Long Leaf	5 lbs. " "	2000	1443	72.15	19.31	22.02
CRL	Sawn New Mexico Pine	5 lbs. " "	200	80	40.00	22.63	28.24
CRM	Sawn Arizona Pine	5 lbs. " "	1200	523	43.58	22.91	27.27
CRE	Hewn Texas Gum	5 lbs. " "	400	77	19.25	23.10	33.80
CRH	Hewn Gum—Plated in 1923	5 lbs. " "	200	72	36.00	22.23	28.92
CRO	Sawn Texas Gum	5 lbs. " "	400	154	38.50	21.52	28.57
CRS	Sawn Gum—Plated in 1924	5 lbs. " "	200	81	40.50	21.99	27.91
CRF-CRI	Hewn Red Oak	5 lbs. " "	589	342	58.06	21.13	24.49
CRG	Hewn White Oak	5 lbs. " "	200	151	75.50	20.33	21.43
CRP-CRT	Sawn Red Oak	5 lbs. " "	587	293	49.91	21.94	26.09
CRR	Sawn White Oak	5 lbs. " "	200	137	68.50	20.77	22.64
CRU	Sawn Douglas Fir	5 lbs. " " 5/8" Perf.	200	160	80.00	19.61	20.69
CRW	Sawn Douglas Fir	5 lbs. " " 1 1/16" Perf.	401	245	61.10	21.04	24.00
CRX-CRY	Sawn Douglas Fir—Plated in 1923	5 lbs. " "	391	343	87.72	18.55	19.35
	Average of all 5 lb. Creosote Treatments		8143	4930	60.54	20.99	24.00

*Estimated without use of curve because percentage removed is beyond limits which Forest Products Laboratory recommends be used.
†Estimated without use of curve because expected average life indicated by using curve is below the actual average life to date.

Statement "A" (Continued)

Symbol	Kind of Wood	All 7 lb. Creosote Treatments Treatment	Number Inserted in 1922	Number Removed Jan. 1, 1947	Percent Removed Jan. 1, 1947	Average Life to Jan. 1, 1947	Expected Average Life
SRA	Hewn Texas Pine	7 lbs. Rueping Creosote	400	286	71.50	20.55	22.02
SRB	Hewn New Mexico Pine	7 lbs. " "	400	195	48.75	22.11	26.37
SRJ	Sawn Texas Pine—Wide Ring	7 lbs. " "	200	149	74.50	20.78	21.62
SRL	Sawn New Mexico Pine	7 lbs. " "	191	141	73.82	21.53	21.82
SRM	Sawn Arizona Pine	7 lbs. " "	1000	414	41.40	22.78	27.91
SRE	Hewn Texas Gum	7 lbs. " "	400	74	18.50	23.49	33.80
SRH	Hewn Texas Gum—Plated in 1923	7 lbs. " "	200	72	36.00	22.30	28.92
SRO	Sawn Texas Gum	7 lbs. " "	390	202	51.79	21.54	25.53
SRS	Sawn Gum—Plated 1923	7 lbs. " "	200	80	40.00	21.50	28.24
SRF-SRI	Hewn Red Oak	7 lbs. " "	600	402	67.00	21.53	22.86
SRG	Hewn White Oak	7 lbs. " "	192	115	59.90	21.11	24.24
SRP-SRT	Sawn Red Oak	7 lbs. " "	590	465	78.81	21.24	22.29†
SRR	Sawn White Oak	7 lbs. " "	199	172	86.43	19.40	19.67
SRU-SRY	Sawn Douglas Fir	7 lbs. " "	400	388	97.00	18.84	18.99*
SRX	Sawn Douglas Fir—Plated in 1923	7 lbs. " " 5/8" Perf.	200	200	100.00	18.75	18.75**
SRW	Sawn Douglas Fir	7 lbs. " " 1 1/16" Perf.	400	286	71.50	20.56	22.02
	Average of all 7 lb. Creosote Treatments		5962	3641	61.07	21.39	24.00

Symbol	Kind of Wood	All 50–50 Creosote–Petroleum Mixture Treatments Treatment	Number Inserted in 1922	Number Removed Jan. 1, 1947	Percent Removed Jan. 1, 1947	Average Life to Jan. 1, 1947	Expected Average Life
MA	Hewn Texas Pine	7 lbs. Ruep. Mix. 50% Creo. 50% Petrol.	399	233	58.40	22.70	24.49
MB	Hewn New Mexico Pine	7 lbs. " " " " " "	392	143	36.48	23.05	28.92
MJ	Sawn Texas Pine	7 lbs. " " " " " "	202	171	84.65	20.76	21.51†
ML	Sawn New Mexico Pine	7 lbs. " " " " " "	200	115	57.50	21.94	24.49
MM	Sawn Arizona Pine	7 lbs. " " " " " "	983	444	45.17	22.93	27.27
ME-MH	Hewn Gum	7 lbs. " " " " " "	1000	200	20.00	23.26	33.33
MO-MS	Sawn Gum	7 lbs. " " " " " "	992	227	22.88	23.17	32.43
MF-MI	Hewn Red Oak	7 lbs. " " " " " "	977	586	59.98	21.58	24.24
MG	Hewn White Oak	7 lbs. " " " " " "	200	116	58.00	21.80	24.49
MP-MT	Sawn Red Oak	7 lbs. " " " " " "	980	636	64.90	21.16	23.30
MR	Sawn White Oak	7 lbs. " " " " " "	200	145	72.50	20.37	21.82
MU-MX	Sawn Douglas Fir—5/8" Perf.	7 lbs. " " " " " "	400	362	90.50	18.33	18.78*
MW-MY	Sawn Douglas Fir—1 1/16" Perf.	7 lbs. " " " " " "	600	432	72.00	19.59	22.02
MV	Sawn White Fir	7 lbs. " " " " " "	200	117	58.50	21.37	24.49
	Average of all 50–50 Creosote Petroleum Mix. Treatments		7725	3927	50.83	21.87	25.81

*Estimated without use of curve because percentage removed is beyond limits which Forest Products Laboratory recommends be used.
**Test completed. Figure shown is actual average life of group.
†Estimated without use of curve because expected average life indicated by using curve is below the actual average life to date.

Statement "A" (Continued)

Symbol	Kind of Wood	All Zinc–Petroleum Treatments Treatment	Number Inserted in 1922	Number Removed Jan. 1, 1947	Percent Removed Jan. 1, 1947	Average Life to Jan. 1, 1947	Expected Average Life
OZA	Hewn Texas Pine	Zinc ½ lb. followed by 5 lbs. Petrol.	391	391	100.00	17.71	17.71**
OZB	Hewn New Mexico Pine	" " " " " "	401	170	42.39	22.39	27.27
OZJ	Sawn Texas Pine—Wide Ring	" " " " " "	200	168	84.00	17.21	20.34
OZL	Sawn New Mexico Pine	" " " " " "	200	152	76.00	20.93	21.62
OZM	Sawn Arizona Pine	" " " " " "	797	395	49.56	21.68	25.81
OZD	Hewn New Mexico Spruce	" " " " " "	401	300	74.81	20.06	21.82
OZE-OZH	Hewn Gum	" " " " " "	388	346	89.18	18.02	19.67
OZO-OZS	Sawn Gum	" " " " " "	391	376	96.16	16.03	16.23*
OZF-OZI	Hewn Red Oak	" " " " " "	401	384	95.76	17.34	17.54*
OZG	Hewn White Oak	" " " " " "	200	200	100.00	18.03	18.03**
OZP-OZT	Sawn Red Oak	" " " " " "	399	394	98.75	15.30	15.35*
OZR	Sawn White Oak	" " " " " "	199	197	98.99	16.29	16.34*
OZW-OZY	Sawn Douglas Fir 1 1/16" Perf.	" " " " " "	988	946	95.75	11.65	11.85*
		Average of all Zinc–Petroleum Treatments	5356	4419	82.51	17.46	20.51

Symbol	Kind of Wood	All Zinc Creosote Petroleum Treatments Treatment	Number Inserted in 1922	Number Removed Jan. 1, 1947	Percent Removed Jan. 1, 1947	Average Life to Jan. 1, 1947	Expected Average Life
ZMA	Hewn Texas Pine	Zinc ½ lb. followed by 30% Creo. 70% Petroleum Mixture	382	299	78.27	19.59	21.05
ZMB	Hewn New Mexico Pine	" " " "	348	267	76.72	20.87	21.24
ZMJ	Sawn Texas Pine—Wide Ring	" " " "	188	160	85.11	20.22	20.97†
ZML	Sawn New Mexico Pine	" " " "	198	182	91.92	20.55	20.95*
ZMM	Sawn Arizona Pine	" " " "	789	565	71.61	21.19	22.02
ZMD	Hewn New Mexico Spruce	" " " "	200	200	100.00	18.07	18.07**
ZME-ZMH	Hewn Gum	" " " "	400	204	51.00	21.96	25.81
ZMO-ZMS	Sawn Gum	" " " "	400	337	84.25	20.36	21.16†
ZMF-ZMI	Hewn Red Oak	" " " "	400	372	93.00	18.70	19.05*
ZMG	Hewn White Oak	" " " "	200	188	94.00	18.04	18.34*
ZMP-ZMT	Sawn Red Oak	" " " "	400	397	99.25	16.46	16.51*
ZMR	Sawn White Oak	" " " "	194	192	98.96	16.81	16.86*
ZMU	Sawn Douglas Fir 5/8" Perf.	" " " "	200	200	100.00	12.55	12.55**
ZMW-ZMY	Sawn Douglas Fir 1 1/16" Perf.	" " " "	600	568	94.67	13.06	13.31*
ZMX	Sawn Douglas Fir—Plated 1923	" " " "	199	199	100.00	12.12	12.12**
		Average of all Zinc Creosote Petroleum Treatments	5098	4330	84.94	18.39	19.83

*Estimated without use of curve because percentage removed is beyond limits which Forest Products Laboratory recommends be used.
**Test completed. Figure shown is actual average life of group.
†Estimated without use of curve because expected average life indicated by using curve is below the actual average life to date.

Statement "A" (Continued)

Symbol	Kind of Wood	Straight Zinc Treatments Treatment	Number Inserted in 1922	Number Removed Jan. 1, 1947	Percent Removed Jan. 1, 1947	Average Life to Jan. 1, 1947	Expected Average Life
ZA	Hewn Texas Pine	Zinc ½ lb.	400	400	100.00	8.84	8.84**
ZJ	Sawn Texas Pine—Wide Ring	" " "	400	400	100.00	9.62	9.62**
ZK	Sawn Texas Pine—Long Leaf	" " "	200	200	100.00	12.92	12.92**
ZF-ZH	Hewn Gum	" " "	400	400	100.00	8.44	8.44**
ZO-ZS	Sawn Gum	" " "	396	396	100.00	8.36	8.36**
ZF-ZI	Hewn Red Oak	" " "	400	400	100.00	8.44	8.44**
ZP-ZT	Sawn Red Oak	" " "	398	398	100.00	8.03	8.03**
	Average of all straight Zinc Treatments		2594	2594	100.00	8.95	8.95**

Summary of Treatment Results, All Woods

Symbol	Treatment	Number Inserted in 1922	Number Removed Jan. 1, 1947	Percent Removed Jan. 1, 1947	Average Life to Jan. 1, 1947	Expected Average Life
CR	5 lbs. Rueping Creosote	8143	4930	60.54	20.99	24.00
SR	7 lbs. Rueping Creosote	5962	3641	61.07	21.39	24.00
M	7 lbs. Rueping Mixture 50% Creo. 50% Petroleum	7725	3927	50.83	21.87	25.81
OZ	Zinc ½ lb. followed by 5 lbs. Petroleum	5356	4419	82.51	17.46	20.51
ZM	Zinc ½ lb. followed by 30% Creo. 70% Petr. Mixture	5098	4330	84.94	18.39	19.83
Z	Zinc ½ lb.	2594	2594	100.00	8.95	8.95**

**Test completed. Figure shown is actual average life of group.

years is indicated. To date, 5-lb. and 7-lb. straight creosote treatments show about 61 percent removed from track and an expected average life of 24 years, while the 7-lb. 50–50 creosote-petroleum solution test ties are about 51 percent removed from track with an indicated average expected life of about 26 years. This 7-lb. 50–50 creosote-petroleum treatment is the forerunner of the present Santa Fe standard preservative for cross ties, which is an 8-lb. 50–50 creosote-petroleum mixture at the Somerville and Wellington treating plants, and an 8-lb. 45–55 at the Albuquerque and National City plants.

Northern Pacific Railway

Tie Record Test Track No. 8-A Near Paradise, Mont.

Embankment, black sandy loam and cinders, about 5 ft. high. Six inches Perma gravel under ties. 90-lb. rail, 19 ties per panel. Northern Pacific standard angle bars and 7 in. by 9 in. tie plates.

198 Coast Douglas fir ties, air-seasoned near Tacoma, Wash., from October 1917 to December 1919. Treated at Paradise, Mont., in December 1919. Piled near M.P. 1 until placed in track in August 1921. Treated by Lowry process with straight creosote, 8 lb. per cu. ft.

24 Montana western yellow pine ties
24 Montana Douglas fir ties
24 Montana hemlock ties
24 Montana cottonwood ties
24 Montana tamarack (larch) ties
24 Coast Douglas fir ties

Air-seasoned at Paradise tie plant from May 1919 to June 1920. Treated at Paradise in June 1920 by Lowry process with 50–50 creosote-petroleum mixture, 8 lb. per cu. ft. Placed in track in August 1921.

Record of Annual Renewals and Results of Final Inspection

Placed 1921	*Coast Fir*	*Pine*	*Mont. Fir*	*Hemlock*	*Cotton-wood*	*Tam. (Larch)*	*Coast Fir*	*Total*
Total	198	24	24	24	24	24	24	342
Renewed								
1930	3	----	-----	------	1	-----	----	4
1931	1	----	-----	------	3	-----	----	4
1932		----	-----	------	------	-----	----	0
1933		----	-----	------	------	-----	1	1
1934		----	-----	------	------	-----	----	0
1935		----	-----	------	------	-----	----	0
1936		----	-----	------	------	-----	----	0
1937	2	----	-----	------	------	-----	----	2
1938	5	----	-----	1	3	3	----	12
1939	14	3	1	4	4	5	4	35
1940	3	2	1	------	------	-----	----	6
1941	48	----	-----	------	1	3	----	52
1942		----	-----	------	------	-----	----	0
1943	113	3	8	19	7	12	14	176
1944		----	-----	------	------	-----	----	0
1945	2	1	-----	------	1	-----	1	5
1946		----	-----	------	------	-----	----	0
1947	4	4	4	------	4	-----	----	16
Total renewed	195	13	14	24	24	23	20	313
% Renewed	98.5	54.2	58.3	100.0	100.0	95.8	83.3	91.5
Average life of ties removed	20.83	22.0	22.64	21.13	19.33	20.22	20.8	0. 82

Tabulation Showing Actual Performance to August 30, 1947 of Ties in Test Tracks of the Northern Pacific Railway

Untreated and treated with straight creosote and treated with 50–50 creosote-petroleum solution

Year Inserted	Original Number Inserted	Total Removed	Percent Removed	Actual Average Life in Track to 8–30–47	Expected Average Life FPL. Curve
Ties placed out of face, near Grassy Point, Duluth, Minn.					
White oak—untreated					
1922	100	93	93	14.1	14 years
Birch—treatment 6.25 lb., creosote, Lowry					
1922	98	0	0	25.0	-------
Birch—treatment 7 lb., creosote-petroleum, Lowry					
1922	101	0	0	25.0	-------
Maple—treatment 6.25 lb., creosote, Lowry					
1922	101	4	4	20.25	34 years
Maple—treatment 7 lb., creosote-petroleum, Lowry					
1922	100	20	20	19.55	27 years
Red oak—treatment 6.25 lb., creosote, Lowry					
1922	100	0	0	25.0	-------
Red oak—treatment 7 lb., creosote-petroleum, Lowry					
1922	100	0	0	25.0	-------
Ties placed out of face, near Plateau, Mont.					
White oak—untreated					
1923	120	120	100	10.50	-------
Birch—treatment 6.25 lb., creosote, Lowry					
1923	101	0	0	24.0	-------
Birch—treatment 7 lb., creosote-petroleum, Lowry					
1923	100	7	7	22.0	37 years
Maple—treatment 6.25 lb., creosote, Lowry					
1923	101	2	2	22.0	41 years
Maple—treatment 7 lb., creosote-petroleum, Lowry					
1923	101	29	29	18.48	30 years
Red oak—treatment 6.25 lb., creosote, Lowry					
1923	100	7	7	22.0	37 years
Red oak—treatment 7 lb., creosote-petroleum, Lowry					
1923	100	17	17	22.0	31 years
Rock elm—treatment 7 lb., creosote-petroleum, Lowry					
1923	50	7	14	22.0	33 years

Hemlock Test Track—Missoula, Mont.

Early in 1910, the Northern Pacific established a test track near Missoula, Mont., which consisted of 1072 Inland Empire hemlock ties, 436 western larch, 166 Rocky Mountain Douglas fir, 102 true fir, 18 Engelmann spruce, and 6 ties of other species. The entire test is located in main line track at the west end of the Missoula yard.

All ties in the test track were treated by the Lowry pressure process with 6¾ lb. per cu. ft. of a creosote-coal tar solution, consisting of 80 percent Grade 1 creosote and 20 percent refined coal tar. The ties were originally laid without tie plates, but after about 2 years were equipped with 7-in. by 9-in. tie plates. In 1926 the track was relaid with 100-lb. rail and 7¾-in. by 10¾-in. Northern Pacific standard plates. The ballast is ordinary pit-run gravel and drainage is not considered good.

Since 1928 the experiment station has assisted in the annual inspections of these ties. At the 1945 inspection, after 35 years of service, renewals of the western hemlock ties amounted to 83.9 percent and the indications are that the average life will be approximately 30 years.

In considering the life of these ties, it should be understood that though the test track is on the main line it is not a high-speed track, because of its proximity to the Missoula yard. Nor does the track contain steep grades and sharp curves. Officers of the Northern Pacific believe that the average life figures indicated by this test will be somewhat higher than can be obtained throughout the Rocky Mountain division.

Comparative service records for the experimental ties of each species in this test track are given in the table.

Condition of Railway Ties in the Northern Pacific Test Track at Missoula, Mont.

Ties set in March 1910

Description of Ties and Preservative Treatment	Average Age at Time Inspected August 1945	Number in Test	Total Renewals because of Wear, Breakage, Splitting and Decay	Estimated Average Life
	Years		Percent	Years
Western hemlock.—Pressure treated with creosote-coal tar solution (80 percent grade 1 creosote and 20 percent refined coal tar), 6¾ lb. per cu. ft.	35.4	1072	83.9	30.2
Western larch.—Same treatment and preservative	35.4	436	68.8	32.4
Douglas fir.—Same treatment and preservative	35.4	166	50.0	36.0
True fir (probably Grand fir).— Same treatment and preservative	35.4	102	91.2	29.8
Engelmann spruce.—Same treatment and preservative	35.4	18	94.4	25.4
Idaho white pine.—Same treatment and preservative	35.4	2	100.0	30.5*
Ponderosa pine.—Same treatment and preservative	35.4	3	33.3	34.0
Aspen.—Same treatment and preservative	35.4	1	100.0	35.0*
Summarization				
Treated ties, all species	35.4	1800	77.6	31.2

*Actual average life (end of test).

Thompson Falls, Mont., Test Track

In order to carry on this study a test track was established in the main line of the railroad during October 1915, the Forest Service and the Northern Pacific Railway cooperating. The purpose was to determine the comparative durability of creosoted Douglas fir, white fir, ponderosa pine, and western larch ties. In addition, it was desired to compare the value of Vignoles rail chairs with standard Northern Pacific plates in reducing mechanical wear and splitting.

This test track originally included 1675 ties, of which 1575 were creosoted and 100 were set untreated. It contains 489 ft. of tangent between a reverse curve of 1 deg. and 2 deg., and it is considered to be fairly representative of the results obtainable from the various species under main line conditions.

About half of the test ties were equipped with Vignoles bolted rail fastenings, which provided for all lateral and vertical adjustments of the rail to the tie without removing bolts. The remainder of the ties were originally equipped with 7-in. by 9-in. Northern Pacific tie plates. The track was originally laid with 90-lb. rail, but in 1925 the entire test track was relaid with 100-lb. rail. When this work was done all of the old Northern Pacific tie plates and Vignoles rail chairs were replaced with the new and latest type of Northern Pacific tie plates. The principal reason for removing all of the rail chairs was that the nuts holding the plates could not be properly tightened because of worn-out threads. As long as it was possible to use them, the Vignoles rail chairs rendered good service in preventing excessive plate wear and splitting of the ties.

Comparative data on the durability of the ties placed in the track are presented in the table. All untreated ties, consisting of 50 Rocky Mountain Douglas fir and 50 western larch ties, were replaced during the period from 1921 to 1926 because of decay. The untreated Douglas fir ties gave an average life of 7.5 years and the untreated larch, an average life of 6.9 years. In October 1944, when, after 29 years of service, the last inspection of this test track was made, all but one of the treated ties originally set had also been renewed. The treated ties of Douglas fir and western larch gave an average life of 23.3 nd 23.4 years, respectively; those of white fir 23.0 years, the lodgepole pine 22.2 years, and the ponderosa pine 26.0 years.

Since the weighted average life of each group of experimental ties set in October 1915 has been determined, this study is now considered closed.

CONDITION OF RAILWAY TIES IN THE NORTHERN PACIFIC TEST TRACK NEAR THOMPSON FALLS, MONT.

Ties set in October 1915

Description of Ties and Preservative Treatment	*Average Age at Time Inspected, October 1944*	*Number in Test**	*Total Renewals because of Wear, Breakage, Splitting and Decay*	*Average Life*
	Years		*Percent*	*Years*
Douglas fir.—Pressure treated with creosote, 6.2 lb. per cu. ft.	29.0	381	100.0	23.3
Douglas fir.—Untreated		50	100.0	7.5
Western larch.—Pressure treated with creosote, 9.0 lb. per cu. ft.	29.0	368	100.0	23.4
Western larch.—Untreated		50	100.0	6.9
Lodgepole pine.—Pressure treated with creosote, 8.6 lb. per cu. ft.	29.0	190	100.0	22.2
Grand (white) fir.—Pressure treated with creosote, 9.1 lb. per cu. ft.	29.0	196	100.0	23.0
Ponderosa pine.—Pressure treated with creosote, 7.3 lb. per cu. ft.	29.0	368	99.7	26.0
Summarization				
Treated ties, all species	29.0	1503	99.9	23.8
Untreated ties, all species		100	100.0	7.2

*Originally there were 72 other ties in the test rack, or a total of 1575. The 72 ties eliminated were sound and serviceable at the time of removal.

PLAINS, MONT., TEST TRACK

Thirty-five years ago the Forest Service entered into a cooperative study of cross ties with the Northern Pacific Railway. The investigation consisted in three separate experiments: First, tests to determine the green weight and rate of seasoning of timbers cut in different months; second, tests to determine the absorptive power of seasoned timbers cut in different months; third, tests to determine the comparative durability of green, of seasoned, and of treated timbers when laid under similar conditions with various tie plates and rail fastenings in a test track. The third experiment, dealing with durability, is the only one which will be described in this report.

In order to carry on the durability study, the railroad established a test track in its main line near Plains, Mont., early in 1907. The test included 2260 untreated western larch and Douglas fir ties plus 390 zinc chloride treated ties of the same species. Treatment of the ties was done under pressure, using a 6-percent solution of zinc chloride. Absorption of the preservative amounted to approximately 0.8 lb. per cu. ft. All of the treated ties and most of the untreated were set in a filled roadbed which is well drained.

The results of this experiment, given in the table, show that the average life for the untreated larch was 7.35 years and for the untreated Douglas-fir, 7.65 years.

The treated Douglas fir ties gave an average life of 17.5 years and the treated western larch, an average life of 18.6 years. The service life obtained from these zinc chloride treated ties is considered to be above the average generally obtainable from this type of preservative. After some years of service all of the ties in this test were turned over, which procedure undoubtedly increased their life. The use of a 6-percent solution resulting in a net retention of 0.8 lb. of dry salt per cu. ft., rather than the 4-percent solution with ½-lb. net retention specified in many instances for zinc chloride treatments, also tended to prolong the life of these test ties.

Summary of Results for the Northern Pacific Test Track Near Plains, Mont.

Ties set in spring of 1907

Description of Ties and Preservative Treatment	Date of Final Inspection	Number in Test	Total Renewals because of Wear, Breakage, Splitting and Decay	Average Life
			Percent	Years
Douglas fir.—Pressure treated with zinc chloride, 0.8 lb. per cu. ft.	June 1932	197	100.0	17.5
Douglas fir.—Green, untreated	June 1916	570	100.0	7.6
Douglas fir.—Seasoned, untreated	June 1916	571	100.0	7.7
Western larch.—Pressure treated with zinc chloride, 0.8 lb. per cu. ft.	June 1932	193	100.0	18.6
Western larch.—Green, untreated	June 1916	551	100.0	7.3
Western larch.—Seasoned, untreated	June 1916	568	100.0	7.4
	Summarization			
Treated ties, both species		390	100.0	18.0
Untreated ties, both species		2260	100.0	7.5

Cottonwood Test Track—Lolo, Mont.

Soon after the completion of the Northern Pacific tie-treating plant at Paradise, Mont., in April 1908, the railroad established several test tracks. One of these test tracks was constructed in March 1910 near Lolo, Mont., in the Bitterroot branch line. In it were 261 creosoted cottonwood ties cut in western Montana.

The ties were air seasoned, not bored nor incised, and were treated by the Lowry pressure process. They were impregnated with a solution of 80 percent grade 1 creosote and 20 percent refined coal tar. Net absorption of the preservative amounted to approximately 8 lb. per cu. ft. of wood. The ties were originally laid with dirt ballast and 56-lb. rail. In 1918 the ties were equipped with 6½-in. by 8-in. plates, and in 1923 the track was relaid with 85-lb. rail. Traffic on this branch is not heavy, but during the period when the ties were not protected by tie plates there was some damage from mechanical wear.

For the past 12 years a representative of the experiment station has accompanied officers of the railroad on their annual inspections of these experimental ties. At the 1945 inspection, after 35 years of service, 154 or 59 percent of the original ties were still in place. Of this number, 21 were classed as being in good condition and capable of giving at least 5 additional years of service, 84 were classified as being in fair condition with an additional life expectancy of 3 to 4 years, and 49 were classed as badly decayed and needing renewal within about 2 years. With 107, or 41 percent of the original ties removed in 35 years, over 90 percent of their average life has been realized. It is expected, therefore, that the average life to be shown by final figures will be close to 37 years.

The results obtained from this study clearly show the wisdom and economy of treating ties of the so-called minor species, such as cottonwood.

The detailed service records for this installation are contained in the table.

CONDITION OF RAILWAY TIES IN THE NORTHERN PACIFIC TEST TRACK (BITTERROOT BRANCH LINE) NEAR LOLO, MONT.

Ties set in March 1910

Description of Ties and Preservative Treatment	Average Age at Time Inspected August 1945	Number in Test	Condition of Ties, August 1945				Est. Average Life
			Good*	Fair†	Poor‡	Removed because of Wear, Splitting, Breakage and Decay	
	Years		Percent	Percent	Percent	Percent	Years
Cottonwood.—Pressure treated with creosote–coal tar solution (80 percent grade 1 creosote and 20 percent refined coal tar), 8 lb. per cu. ft.	35.4	261	8.0	32.2	18.8	41.0	37

*"Good" condition means life expectancy of 5 years or more.
†"Fair" condition means life expectancy of 3 to 4 years.
‡"Poor" condition means life expectancy of 1 to 2 years.

Great Northern Railway

SERVICE RECORD—2316 WHITE BIRCH TEST TIES—STONE ARCH BRIDGE—MINNEAPOLIS

Originally Placed 1924

Year	Number Removed Each Year	Accumulative Total Removed	Percent Removed	Number of Years in Service	Tie Year Life	Accumulative Tie Year Life	Average Life of Ties Removed in Years to October 1947
1924	0	0	0	0	0	0	0
25	0	0	0	1	0	0	1
26	0	0	0	2	0	0	2
27	0	0	0	3	0	0	3
28	0	0	0	4	0	0	4
29	0	0	0	5	0	0	5
1930	0	0	0	6	0	0	6
31	0	0	0	7	0	0	7
32	0	0	0	8	0	0	8
33	0	0	0	9	0	0	9
34	0	0	0	10	0	0	10
1935	0	0	0	11	0	0	11
36	0	0	0	12	0	0	12
37	0	0	0	13	0	0	13
38	0	0	0	14	0	0	14
39	0	0	0	15	0	0	15
1940	29	29	1.2	16	464	464	16
41	38	67	2.9	17	646	1,110	16.6
42	5	72	3.1	18	90	1,200	16.7
43	8	80	3.4	19	152	1,352	17.0
44	10	90	3.9	20	200	1,552	17.2
1945	206	296	12.8	21	4,326	5,878	19.8
46	53	349	15.0	22	1,166	7,044	20.1
47	88	437	18.9	23	2,024	9,068	20.7

An earlier report of this test was published in AREA Proceedings, Vol. 41, 1940, page 500, and in the AWPA Proceedings for 1940.

Service Record—9337 Creosoted White Birch Test Ties Originally Placed 1908

Year	Number Removed Each Year	Accumulative Totals Removed	Percent Removed	Number of Years in Service	Tie Year Life	Accumulative Tie Year Life	Average Life of Ties Removed in Years to October 1947
1908	0	0	0	0	0	0	
9	0	0	0	1	0	0	
1910	0	0	0	2	0	0	
11	0	0	0	3	0	0	
12	10	10	0	4	40	40	4.0
13	90	100	1	5	450	490	4.9
14	115	215	2	6	690	1, 180	5.5
1915	230	445	5	7	1, 610	2, 790	6.3
16	360	805	9	8	2, 880	5, 670	7.0
17	36	841	9	9	324	5, 994	7.1
18	36	877	9	10	360	6, 354	7.3
19	994	1, 871	19	11	10, 934	17, 288	9.2
1920	79	1, 950	21	12	948	18. 236	9.4
21	39	1, 989	21	13	507	18, 743	9.5
22	240	2, 229	24	14	3, 360	22, 103	9.9
23	402	2, 631	28	15	6, 030	28, 133	10.7
24	136	2, 767	28	16	2, 176	30, 309	10.9
1925	29	2, 796	29	17	493	30, 802	11.0
26	278	3, 074	32	18	5, 004	35, 806	11 6
27	201	3, 275	34	19	3, 819	39, 625	12.1
28	221	3, 496	37	20	4, 420	44, 045	12.6
29	221	3, 717	39	21	4, 641	48, 686	13.1
1930	359	4, 076	43	22	7, 898	56, 584	13.9
31	96	4, 172	44	23	2, 208	58, 792	14.1
32	86	4, 258	45	24	2, 064	60, 856	14.3
33	48	4, 306	45	25	1. 200	62, 056	14.4
34	52	4, 358	46	26	1, 352	63, 408	14.5
1935	14	4, 372	46	27	378	63, 786	14.6
36	95	4, 467	47	28	2, 660	66, 446	14 9
37	100	4, 567	48	29	2 900	69 345	15 2
38	210	4, 777	50	30	6, 300	75, 645	15.8
39	363	5, 140	54	31	11, 253	86, 899	16.9
1940	374	5, 514	59	32	11, 968	98, 867	17.9
41	430	5, 944	64	33	14, 190	113, 057	19.0
42	186	6, 130	66	34	6, 324	119, 381	19.5
43	164	6, 294	67	35	5, 740	125, 121	20.0
44	220	6, 514	70	36	7, 920	133, 041	20.4
1945	301	6, 815	73	37	11, 137	144, 178	21.2
46	402	7, 217	77	38	15, 276	159, 454	22.1
47	290	7, 507	80	39	11, 310	170, 764	22.8

Original total 9537 was reduced by 200 to 9337 because of derailment.
An earlier report of this test was published in the AREA Proceedings, Vol. 41, 1940, page 499, and in the AWPA Proceedings for 1940.

Report on Assignment 7

Incising Forest Products

W. P. Arnold (chairman, subcommittee), F. W. Gottschalk, F. W. Hillman, B. D. Howe, R. P. Hughes, A. J. Loom, T. H. Strate, C. H. Wakefield.

Your committee submits as information the following report of progress on its study of incising forest products.

Tests were run at the Orrville laboratory of the Koppers Company to study the effect of incising. The variables in these tests were length of pressure period, number of incisions, and two species, southern yellow pine and white oak.

Matched samples of both heart southern yellow pine and heart white oak, one of each species incised with the standard AREA pattern, and the other sample of each species unincised, were treated with grade 1 creosote on a Rueping schedule.

Initial air	60 lb. per sq. in.	30 min.
Pressure	150 lb. per sq. in.	6 hours
Temperature	185 deg. F.	
Final vacuum	27 in.	30 min.

Moisture content of both woods was about 23 percent. Retentions of the pieces in lb. per cu. ft. were:

	Unincised	*Incised*
White oak	1.67	2.74
Southern yellow pine	11.99	11.99

Cross sections cut from the middle of each sample of white oak indicated that incising had very little effect on penetration. Penetration of both sections was negligible except at the incised points, where the preservative entered about ⅛ in. around the knife cuts.

Incising the heart yellow pine produced an even line of penetration slightly deeper than the ¾-in. knife cuts. The unincised sample showed at least one area in which penetration was only ½ in. deep. This lack of uniformity was not evident in the incised sample, although the retentions of the incised and unincised pine were identical. Photographs of the sections are presented in Fig. 1.

Matched samples of heart white oak were cut as before, one incised, and the other left unincised. Both were treated in grade 1 creosote by the following schedule.

Initial air	60 lb. per sq. in.
Pressure period	12 hours
Pressure	150 lb. per sq. in.
Temperature	210 deg. F.
Blowback	

Retentions of the pieces in lb. per cu. ft. were 3.45 for the unincised piece, and 5.29 for the incised piece. Each piece was cut in half 48 hours after treatment. There was little evidence that the longer pressure period increased the penetration. As in the first test, penetration was approximately ⅛ in., and extended around the periphery of the slice made by the incision knife. Higher retentions attained in this treatment may be due to the omission of final vacuum. Photographs of the cross sections were not taken.

To test the effectiveness of additional incising on the penetration of creosote in white oak, matched samples were prepared. Two samples were not incised, and two

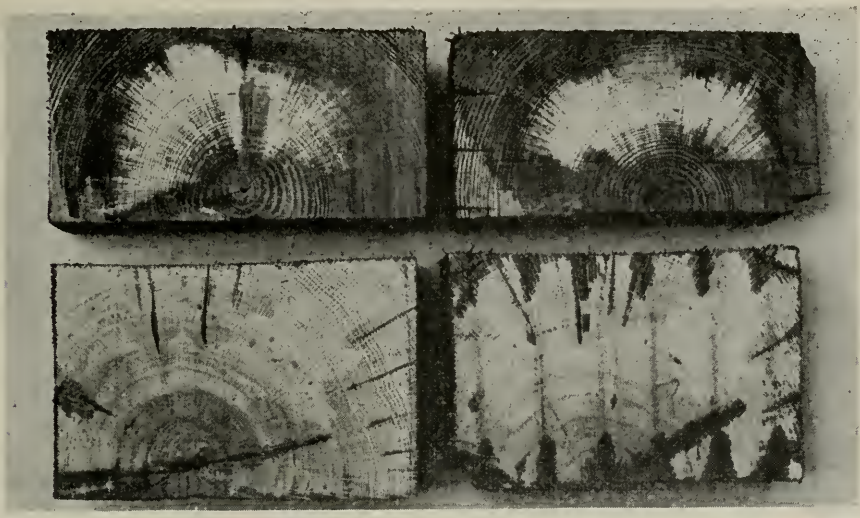

Fig. 1.—Effect of Incising on Penetration in Southern Yellow Pine and White Oak.
Top left, southern yellow pine unincised — Right, pine incised
Bottom left, white oak unincised — Right, oak incised

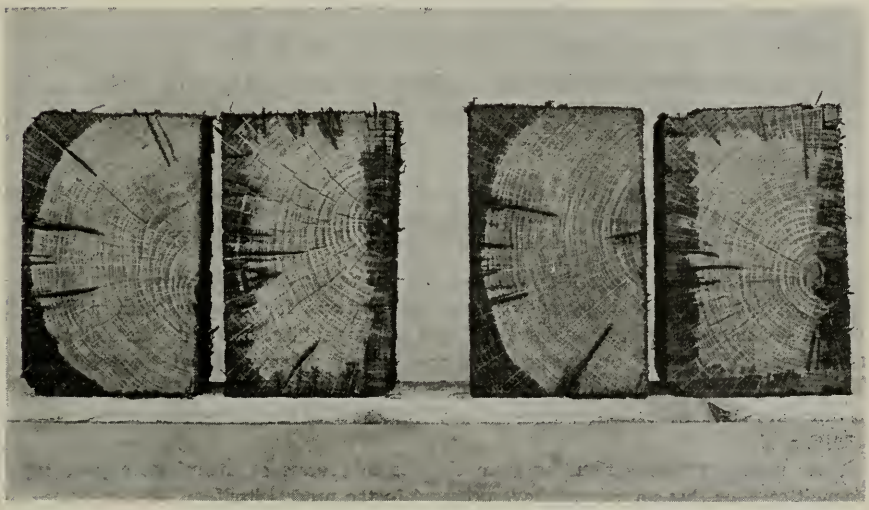

Fig. 2.—From Left to Right, Unincised 6 Hours, Incised 6 Hours, Unincised 12 Hours, and Incised with 12-Hour Pressure.

were run and rerun through the incising machine in such a manner as to achieve a rather uniform pattern with four times the number of incisions as the standard AREA pattern. Two Rueping charges were run, each with one incised and one unincised sample, the first with a 6-hour pressure period and the second with a 12-hour pressure period.

Initial air	60 lb. per sq. in.
Pressure period	6 hours
Pressure	200 lb. per sq. in.
Temperature	210 deg. F.
Final vacuum	30 min. at 27 in.

The retention of the unincised sample was 3.88 lb. per cu. ft.; that of the incised sample was 4.29 lb. per cu. ft.

Initial air	60 lb. per sq. in.
Pressure period	12 hours
Pressure	200 lb. per sq. in.
Temperature	210 deg. F.
Final vacuum	30 min. at 27 in.

The unincised sample had a retention of 5.69 lb. per cu. ft., the incised sample 6.73 lb. per cu. ft. The heartwood penetration on unincised samples was very little with either pressure period. The heartwood penetration in quadruple incised samples reached about the same maximum depth with both 6 and 12-hour schedules, but the line of penetration was more even with the longer pressure period.

The results of this test correspond quite well with those of the first test. Creosote penetration stopped at the depth of the incising marks. However, the increased number of knife marks resulted in more even penetration. No tests were made as to the effect of added incising on the strength of the wood.

Report on Assignment 9

Review the Specifications for Creosote With Particular Respect to Limitation of Residue Above 355 deg. C., and Other Revisions Resulting from Changes in Processes of Manufacture

L. B. Shipley (chairman, subcommittee), R. S. Belcher, Walter Buehler, C. M. Burpee, G. B. Campbell, W. H. Fulweiler, W. R. Goodwin, F. W. Hillman, H. L. Holderman, A. L. Kammerer, J. N. Roche, Henry Schmitz, J. E. Tiedt.

Your committee submits the following progress report as information.

Your subcommittee has reviewed the specifications for creosote with particular respect to limitation of residue above 355 deg. C. This subject had and is receiving very serious consideration. Your subcommittee and a similar committee of the AWPA are making an intensive survey of service records with a view of determining whether there is anything in these records to warrant any limitation of the amount of residue above 355 deg. C.

As regards revisions resulting from changes in process of manufacture your subcommittee finds that no changes have occurred in the process itself.

With respect to an impression recently current that excessive quantities of tar acids, naphthalene and other constituents are now being removed from the creosote, your

subcommittee finds that such is not the case as to the extraction of the low boiling tar acids (phenols), since the extraction of these acids has been common practice for many years. In regard to naphthalene, consideration should be given to the practice in the industry over a long period of years. It is a fact that depending upon the location of manufacture, this constituent which is represented in the specification by the fraction distilling up to 235 deg. C. and limited to a maximum of 25 percent, has varied in any one year from 5 to 20 percent. During the period of the war, in accordance with government regulation, larger percentages were removed, but this is not general practice at the present time. Your subcommittee therefore, finds that, except for the war years, excessive quantities of naphthalene have not been removed.

So far as other constituents are concerned your subcommittee finds that no appreciable quantities are being extracted.

Report on Assignment 11

Preliminary Conditioning of Forest Products for Treatment by Artificial Methods of Seasoning

W. P. Arnold (chairman, subcommittee), R. S. Belcher, P. D. Brentlinger, C. M. Burpee, L. S. Crane, R. F. Dreitzler, H. R. Duncan, F. W. Gottschalk, B. D. Howe, L. A. Olson, R. R. Poux, L. B. Shipley, Hermann von Schrenk.

Your committee submits as information the following report of progress on its study of preliminary conditioning.

Urea Impregnations for Retarding Checks in Red Oak and Southern Pine During Seasoning

Studies were undertaken at Somerville, Tex., (Atchison, Topeka & Santa Fe Railway) to determine whether urea (NH_2CONH_2) would be equally effective for red oak and southern pine as it was for Douglas fir. Heavy concentrations of urea chemical in the outer zone of large fir timbers have been used in commercial practice for a number of years in the Pacific Northwest, thereby providing a means to air-season or kiln-dry Douglas fir timbers without checks or splits.

These experiments with oak and pine were related to possible application for railroad cross ties. The essential details of the pressure impregnation with urea are as follows:

Series	*Material*	*No. of Pieces*	*Condition*	*Species*	*Treating Conc. Percent*	*Retention (Dry Chemical) Lb. per Cu Ft.*
I	Switch ties	10	Green	Red oak	30	0.91
II	Switch ties	10	Green	Red oak	10	0.24
III	Cross ties	20	Green	Red oak	30	1.43
IV	Cross ties	20	Green	Red oak	10	0.41
V	Cross ties	20	Seasoned	Red oak	30	2.39
VI	Cross ties	20	Seasoned	Red oak	10	0.66
VII	Timbers*	47	Green	So. pine	30	1.29
VIII	Timbers*	46	Green	So. pine	10	1.07

*6-in. by 10-in. and 8-in. by 10-in. material.

The test pieces were air-seasoned out of doors in standard stacks, which included similar untreated material. Observations were made at 4½, 6, 12 and 18-month intervals,

the last being the conclusion of the test. The results were tabulated at the end of the 18-month interval, as follows:

Series	*Results at 18 Mont.'s*
I	Same as untreated
II	Same as untreated
III	Slightly less checking than untreated
VI	Same as untreated
V*	No retardation in checking
VI*	No retardation in checking
VII	Much less checking than untreated
VIII	Much less checking than untreated

*The cross ties contained seasoning checks when treated and continued to check during the test period

The only significant findings were for the southern pine timbers, where both retentions appeared to be equal in effectiveness.

All material was given a full-cell pressure treatment with 50–50 creosote-petroleum solution at the end of the 18-month period. The urea processing did not appear to increase penetration absorption or distribution of the preservative.

Retentions of urea in Series III, VII and VIII, which did give beneficial results, were in the neighborhood of 1.07 to 1.43 lb. per cu. ft. Carload quantities of urea are listed at five cents a pound, f.o.b. manufacturing plant; therefore, total processing would cost $16 to $25 per M ft. b.m.

Bibliography

Chemical Pretreatment Speeds Seasoning of Large Items and Avoids Degrade by W. Karl Loughborough, Senior Engineer, U. S. Forest Products Laboratory, Madison, Wis.

The Hygroscopic and Antishrink Values of Chemicals in Relation to Chemical Seasoning of Wood by Edward C. Peck, Wood Technologist, U. S. Forest Products Laboratory, Madison, Wis.

Chemical Seasoning—Urea as an Aid to Seasoning—Progress Report No. 2—West Coast Lumbermen's Association, Seattle, Wash.

Bridge Tie Test

In 1946, the Pennsylvania Railroad decided to conduct a bridge tie test by using green Boulton seasoned oak bridge ties and air-seasoned oak bridge ties. Thus, one charge of dry oak bridge ties was treated and two charges of green oak bridge ties were treated (part of each green charge was cross ties which were not included in the test). All ties were treated at the Orrville, Ohio, plant of the Koppers Company. In the test there were 180 green and 180 dry bridge ties. The dry bridge ties were seasoned for about 16 months prior to treatment.

All bridge ties were placed out of face on a Pennsylvania Railroad bridge between Loudonville and Mansfield, Ohio. Half of the dry ties were placed on the west end of the westbound track, while into the other half of the westbound track, (east end of the bridge) were placed half of the green ties. The remaining half of the dry ties were placed in the east end of the eastbound track and the remaining half of the green ties were placed in the west end of the eastbound track.

It was fortunate that the ties were placed in this manner, since the rail in the eastbound track is 131 lb., while that in the westbound track is 152 lb.

Air-seasoned bridge ties were treated as follows:

Initial air	20 lb. per sq. in.	
Pressure	200 lb. per sq. in.	8 hours
Temperature	210 deg. F.	
Blowback		
Final vacuum		½ hour

Retention on this charge was 6.4 lb. per cu. ft. of 60–40 creosote-coal tar solution.

Approximately half of the green bridge ties were treated as follows:

Boulton	10 hours	
Initial air	50 lb. per sq. in.	
Pressure	200 lb. per sq. in.	6 hours
Temperature	210 deg. F.	
Blowback		
Final vacuum		½ hour

Retention of bridge ties in this charge was 8.5 lb. per cu. ft. of 60–40 creosote-coal tar solution.

The remainder of the green bridge ties was treated as follows:

Boulton	11 hours	
Initial air	40 lb. per sq. in.	
Pressure	200 lb. per sq. in.	7 hours
Blowback		
Final vacuum		½ hour

Retention of bridge ties in this charge was 7.1 lb. per cu. ft. of 60–40 creosote-coal tar solution.

Pictures of this installation were taken on June 17, 1947, and at that time the bridge ties were observed (not inspected) and no severe checking could be detected, in fact, there was no noticeable difference between the two types of ties.

Report on Drying of Wood in Oil Solutions

There has been revived recently the old procedure of drying wood by boiling it in oil. This process is being revived by the Wood Dryers, Inc., B. E. Barksdale, Sr., president, at Charlotte, N. C.

The Wood Dryers' procedure consists of an open tank containing large numbers of steam coils, in which the wood is submerged in a special petroleum solution.

Southern yellow pine wood 4 in. by 8 in. by 16 ft. has been dried successfully from green to 12 to 15 percent moisture content in about 16 hours without serious degrade. The quantity of oil absorbed is not known definitely.

The process is still in the experimental development stage, and whether it can be used for species other than pine is not definitely known. It is highly probable that for hardwoods and more difficult species to season, the temperatures and rates of drying will have to be reduced. As the temperature is reduced, the rate of diffusion of the moisture from the center of the piece to the surface is lowered to a greater extent than the rate of evaporation from the surface.

No tests have been run to determine the effect of temperature on the strength of the wood. It is not believed that the reduction would be serious.

Report of Committee 15—Iron and Steel Structures

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M. Block
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R. P. Davis
W. N. Downey
C. E. Ekberg
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G. V. Guerin, Jr.
O. E. Hager
Shortridge Hardesty
A. R. Harris
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J. E. Yewell
R. W. Young
W. L. Young
Committee

* Died September 20, 1947.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Revisions of Specifications for Steel Railway Bridges and others parts of Chapter 15, submitted for adoption and publication in the Manual ..... page 200
   Test results on impact, presented as information ..... page 207

2. Specifications for fusion welding and gas cutting for steel structures, collaborating with ASTM Committee A–1 on Steel, and the American Welding Society Conference Committee on Bridges.

   Final report, submitted as information, including recommended revision of Fusion Welding (page 15–133 of the Manual) submitted for adoption and publication in the Manual ..... page 212

3. Design of expansion joints involving iron and steel structures.

   No report.

4. Stress distribution in bridge frames-floorbeam hangers.

   No report.

5. Design of bridge details.

   Progress report, presented as information ..... page 213
   Report on rocker shoe assembly test by M. B. Lagaard ..... page 214

6. Shortening of eyebars to equalize the stress.

   Final report, submitted for adoption and publication in the Manual ..... page 231

7. Specifications for cold riveted construction.

.Progress report, presented as information ..... page 234

The Committee on Iron and Steel Structures,
E. S. Birkenwald, *Chairman.*

Roy Alexander Kane

Roy Alexander Kane, a member of the Association since 1946, died at Seattle, Wash., on September 20, 1947. Born at Primghar, Iowa, on September 13, 1889, Mr. Kane received his later education at the University of Illinois, from which he was graduated in 1914 with degree of B.S. in Architecture.

Mr. Kane's railroad experience began in 1917 in the bridge engineer's office of the Union Pacific Railroad in Omaha. In 1927 he was transferred to the Los Angeles & Salt Lake Railroad at Los Angeles, Calif., returning to the Union Pacific at Omaha in 1930. He was made structural engineer on March 1, 1942, in which capacity he served until his death.

Although his membership in the Association was only for a period of about two years, he assisted in the activities of Committee 15 for several years prior to his election to membership.

Report on Assignment 1

Revision of Manual

C. E. Webb (chairman, subcommittee), E. S. Birkenwald, J. L. Beckel, R. P. Davis, O. E. Hager, Jonathan Jones, C. T. Morris, C. H. Sandberg, G. L. Staley, R. A. Van Ness, J. P. Walton.

Specifications for Steel Railway Bridges

The committee recommends the following changes:

104—page 15–4

Add at the end of the paragraph:

Where shallower depth spans are required, they shall be proportioned so that all deflection from the combined effect of live load and impact shall not exceed that obtained for spans of the depth ratios given above.

206—page 15–7

The following should be substituted for paragraph (b).

(b) The direct vertical effect:

Downward forces, distributed equally to the two rails and acting normal to the top-of-rail plane, due, in the case of steam locomotives, to hammer blow, track irregularities, speed effect and car impact, and equalling the following percentage of the axle loads:

(1) For beam spans, stringers, girders, floorbeams, posts of deck truss spans carrying load from floorbeam only, and floorbeam hangers

For L less than 100 ft. ..... $60 - \frac{L^2}{500}$

For L 100 ft. or more ..... $\frac{1800}{L - 40} + 10$

(2) For truss spans ..... $\frac{4000}{L + 25} + 15$

or due, in the case of rolling equipment without hammer blow (diesels, electric locomotives, tenders alone, etc.) to track irregularities, speed effect and car impact, and equalling the following percentage of axle loads:

For L less than 80 ft. ..... $40 - \frac{3L^2}{1600}$

For L 80 ft. or more ..... $\frac{600}{L - 30} + 16$

L = length, in feet, center to center of supports for stringers, longitudinal girders and trusses (main members)

or L = length, in feet, of the longer adjacent longitudinal beam, girder or truss for impact in floorbeams, floorbeam hangers, subdiagonals of trusses, transverse girders, supports for longitudinal and transverse girders and viaduct columns.

Replace Section VIII (pages 15–31 to 15–37 incl.) with the following:

VIII STRUCTURAL AND RIVET STEEL (CARBON GRADE)

801. Structural and Rivet Steel

Except as otherwise specified in this section, structural and rivet steel shall conform respectively to the requirements of the current specifications of the ASTM as follows: for structural steel, Designation A 7; for rivet sheet, Designation A 141.

The steel shall be made by the open-hearth or the electric furnace process.

The chemical composition shall conform to the following table:

	Percent
Phosphorus, max.	Acid 0.06
	Basic 0.04
Sulfur, max.	0.05
Copper, when copper-bearing steel is specified, min.	0.20

The tensile test requirements shall be as follows:

	Structural Steel	*Rivet Steel*
Tensile strength, psi.	60,000–72,000	52,000–62,000
Yield point, min., psi.	0.5 tens. str.	0.5 tens. str.
but in no case less than	33,000	28,000
Elongation in 8 in., min., percent	$\frac{1,500,000}{\text{tens. str.}}$	$\frac{1,500,000}{\text{tens. str.}}$
Elongation in 2 in., min., percent	22	

The crosshead speed of the testing machine, after a stress of ½ the specified yield point is attained and during determination of yield point, shall not exceed 1/16 in. per min. per in. of gage length; and during determination of ultimate strength shall not exceed ½ in. per min. per in. of gage length.

The bend test specimen shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion to an inside diameter which shall bear the following ratio to the thickness of the specimen:

Thickness	*Ratio*
Structural steel, ¾ in. and under	½
" " , over ¾ in. to 1 in., incl.	1
" " , over 1 to 1½ in., incl.	1½
" " , over 1½ to 2 in., incl.	2½
" " , over 2 in.	3
Rivet steel	flat on itself

In order to meet the requirements of Article 607 for the physical properties of full-size annealed forged-head eyebars, the manufacturer of the eyebars may determine the physical properties required for the specimen tests. The steel shall conform to the above requirements as to physical properties other than tensile strength.

Replace Section IX (pages 15–37 to 15–40, incl.) with the following:

IX STRUCTURAL SILICON STEEL

901. Structural Silicon Steel

Except as otherwise specified in this section, structural silicon steel shall conform to the requirements of the current specifications of the ASTM Designation A 94.

The chemical composition shall conform to the following table:

	Ladle Analysis Percent	*Check Analysis Percent*
Carbon, max.	0.40	0.44
Phosphorus, max. Acid	0.06	0.075
Basic	0.04	0.05
Sulfur, max.	0.05	0.063
Silicon, min.	0.20	0.18

The tensile test requirements shall be as follows:

Tensile strength, psi.	80,000–95,000
Yield point, min. psi.	45,000
Elongation in 8 in., min., percent	1,500,000* / tens. str.
Elongation in 2 in., min., percent	1,600,000 / tens. str.
Reduction in area, min., percent	30*

* With reductions for material over ¾ in. thick.

The crosshead speed of the testing machine, after a stress of ½ the specified yield point is attained and during determination of yield point, shall not exceed 1/16 in. per min. per in. of gage length; and during determination of ultimate strength shall not exceed ½ in. per min. per in. of gage length.

The bend test specimen shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion to an inside diameter which shall bear the following ratio to the thickness of the specimen:

Thickness	*Ratio*
¾ in. and under	1
Over ¾ to 1 in., incl.	1½
Over 1 to 1¼ in., incl.	2
Over 1¼ in.	2½

Repair by welding, if necessary, shall be undertaken only after inspection and approval by the engineer or his representative.

Replace Section X (pages 15–40 to 15–43, incl.) with the following:

X HIGH-TENSILE STRUCTURAL AND RIVET STEEL

(in process of development)

Replace Section XI (pages 15–44 to 15–46, incl.) with the following:

XI STRUCTURAL NICKEL STEEL

1101. Structural Nickel Steel

Except as otherwise specified in this section, structural nickel steel shall conform to the requirements of the current specifications of the ASTM Designation A 8.

The chemical composition shall conform to the following table:

	Ladle Analysis Percent	*Check Analysis Percent*
Carbon, max.	0.43	0.45
Manganese, max.	0.80	0.85
Phosphorus, max.	0.04	0.05
Sulfur, max.	0.05	0.063
Nickel	3.00 to 4.00	3.00 to 4.00
Copper, when copper-bearing steel is specified, min.	0.20	0.20

The tensile test requirements shall be as follows:

Tensile strength, psi.	90,000–115 000
Yield point, min., psi.	0.5 tens. str.
but in no case less than	55 000
Elongation in 8 in., min. percent	1,600,000* / tens. str.
Elongation in 2 in., min., percent	1,700,000 / tens. str.
Reduction in area, min., percent	30*

* With reductions for material over ¾ in. thick.

The crosshead speed of the testing machine, after a stress of ½ the specified yield point is attained and during determination of yield point, shall not exceed 1/16 in. per min. per in. of gage length; and during determination of ultimate strength shall not exceed ½ in. per min. per in. of gage length.

The bend test specimen shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion to an inside diameter which shall bear the following ratio to the thickness of the specimen:

Thickness	*Ratio*
¾ in., and under	1½
Over ¾ in. to 1¼ in., incl.	2
Over 1¼ in. to 2 in., incl.	2½

The material shall pass a drift test; in which punched holes with their centers two diameters from a planed edge shall be enlarged by drifting until the diameter is increased 50 percent, without any cracking of the metal. One drift test shall be made from each melt, except that if the material from one melt varies ⅜ in. or more in thickness, both the thickest and the thinnest material shall be tested.

Replace Section XIII (page 15–47) with the following:

XIII STEEL FORGINGS

1301. Steel Forgings

Except as otherwise specified in this section, steel forgings shall conform to the requirements of Grade C 1 of the current specifications of the ASTM Designation A 235.

The chemical composition shall conform to the following table:

	Percent
Manganese, max.	0.90
Phosphorus, max.	0.05
Sulfur, max.	0.05

The tensile test requirements shall be as follows:

Tensile strength, min., psi.	66,000
Yield point, min., psi.	33,000
Elongation in 2 in., min., percent	
Solid diameter or thickness not over 12 in.	23
Solid diameter or thickness over 12 to 20 in., incl.	22
Reduction of area, min., percent	
Solid diameter or thickness not over 12 in.	36
Solid diameter or thickness over 12 to 20 in., incl.	34

The crosshead speed of the testing machine, after a stress of ½ the specified yield point is attained and during determination of yield point, shall not exceed 1/16 in. per min. per in. of gage length; and during determination of ultimate strength shall not exceed ½ in. per min. per in. of gage length.

Replace Section XIV (page 15–47) with the following:

XIV CAST IRON

1401. Cast iron

Cast iron shall conform to the requirements of Class 25 of the current specifications of the ASTM Designation A 48.

Test bars of circular form, cast separately from the castings, shall be of the following dimensions and shall support the following minimum breaking loads applied at midspan:

Controlling Section of Casting, in.	*Nominal Diameter of Test Bar, in.*	*Span between Supports, in.*	*Breaking Load min., lb.*
0.50 and under	0.875	12	1025
0.51 to 1.00	1.20	18	2000
1.01 to 2.00	2.00	24	6800

Over 2.00 the test bar for 1.01 to 2.00 may be used or a larger bar used by agreement with the engineer.

In the event of failure to pass the flexure test, provision is made for an alternative tensile test of a specimen machined from a broken end of a transverse test bar.

Replace Section XV (page 15–47) with the following:

XV MALLEABLE IRON CASTINGS

1501. Malleable Iron Castings

Except as otherwise specified in this section, malleable iron castings shall conform to the requirements of the current specifications of the ASTM Designation A 47.

The tensile test requirements shall be those stated in the following table, for the grade specified by the engineer:

	Grade No. 32510	*Grade No. 35018*
Tensile strength, min., psi.	50,000	53,000
Yield point, min., psi.	32,500	35,000
Elongation in 2 in., min., percent	10	18

The crosshead speed of the testing machine, after a stress of ½ the specified yield point is attained and during determination of yield point, shall not exceed 1/16 in. per min. per in. of gage length; and during determination of ultimate strength shall not exceed ½ in. per min. per in. of gage length.

Replace Part 3—Alloy Steels (pages 15–48.3 to 15–48.6, incl.) with the following:

XVI WROUGHT IRON

1601. Wrought Iron Plates

Wrought iron plates shall conform to the requirements of the current specifications of the ASTM Designation A 42.

The manganese content shall not exceed 0.06 percent.

The tensile test requirements (longitudinal tests only may be made) shall be as follows:

Tensile strength	48,000*
Yield point	27,000
Elongation in 8 in.	14

* Less 1000 psi. for each ⅛ in. over ¾ in., to a minimum of 39,000

Special provisions are made for reduction of minimum tensile strength when a minimum transverse ductility is specified.

Bend test specimens shall bend cold 90 deg. around a pin the diameter of which is 40 times the plate thickness divided by the specified minimum elongation in 8 in.

1602. Wrought Iron Shapes and Bars

Wrought iron shapes and bars shall conform to the requirements of the current specifications of the ASTM Designation A 207.

The manganese content shall not exceed 0.06 percent.

The tensile test requirements shall be as follows:

	Flat Bars and Shapes	*Round, Square and Hexagonal Bars*		
		Under 1⅝ in.	*1⅝ in. to 2½, excl.*	*2½ and over*
Tensile strength, min., psi. ..	46,000*	48,000	47,000	46,000*
Yield point, min., psi.	0.50 T.S.	0.60 T.S.	0.55 T.S.	0.50 T.S.
Elongation in 8 in., min., percent	20	25	22	20
Reduction of area, min., percent	30	40	35	30

* If the area exceeds 12 sq. in., 45,000 psi.

The bend test specimen shall stand being bent cold through 180 deg. around a pin the diameter of which is equal to the thickness of the specimen, without fracture.

1603. Speed of Testing Machine in Tensile Tests

For wrought iron plates, shapes and bars, the crosshead speed of the testing machine, after a stress of ½ the specified yield point is attained and during determination of yield point, shall not exceed 1/16 in. per min. per in. of gage length; and during determination of ultimate strength shall not exceed ½ in. per min. per in. of gage length.

Replace Section XVII (page 15–48.7) with the following:

XVII BRONZE

1701. Bronze

Bronze bearings and expansion plates shall conform to the requirements of the current specifications of the ASTM as follows:

Cast plates: Designation B 22;
Rolled plates: Designation B 100.

Add Section XVIII to be same as Part 3—Alloy Steel (pages 15–48.3 to 15.48.6, incl.) except for changing article numbers from 1600 series to 1800 series.

Pages 15–95 to 15–100, incl.

Specifications for Erection of Steel Railway Bridges

Submitted for reapproval without change.

Page 15–133

Track Anchorage on Bridges and Similar Structures

Submitted for reapproval without change.

Pages 15–119 and 15–120

Classification of Railway Bridges

Submitted for reapproval with the following editorial change:

Page 15–119—Delete paragraphs 1 and 2 and substitute the following:

The classification of a bridge with regard to safe carrying capacity is based on the heaviest moving load of specification type which may be operated over it in regular service without subjecting it to such severe stresses, vibration or wear of parts as to impair its safety or serviceability. Loads in excess of design loads will, if continuously operated, shorten the useful life of the bridge.

Iron and steel bridges shall be classified according to their rated carrying capacity as determined by the AREA Rules for Rating Existing Iron and Steel Bridges.

Page 15–119—Under heading Division of Subject, delete the figure 3 in first line.

Test Results on Impact

Your committee offers the following statement in support of the recommended revision of Article 206 presented on page 200.

In its report for 1946, the committee presented as information certain proposed changes in the impact allowance for railway bridges. The major changes proposed involved a reduction of the impact in beam and girder spans up to about 65 ft. in length, and an increase of the impact in truss spans under steam locomotives. It was further recommended to increase the impact in all spans under rolling equipment without hammer blow.

The research staff of the Engineering Division, AAR, has conducted tests on a considerable number of spans, a complete list of these spans is shown in Table 1. The test results secured on several of these spans have been presented and published by Committee 30—Impact and Bridge Stresses, as shown at the bottom of this table. The analysis of the data secured on the remaining spans has not been completed; however, sufficient progress has been made to determine the total impact effects for all of these spans and these data are shown in Figs. 1, 2 and 3.

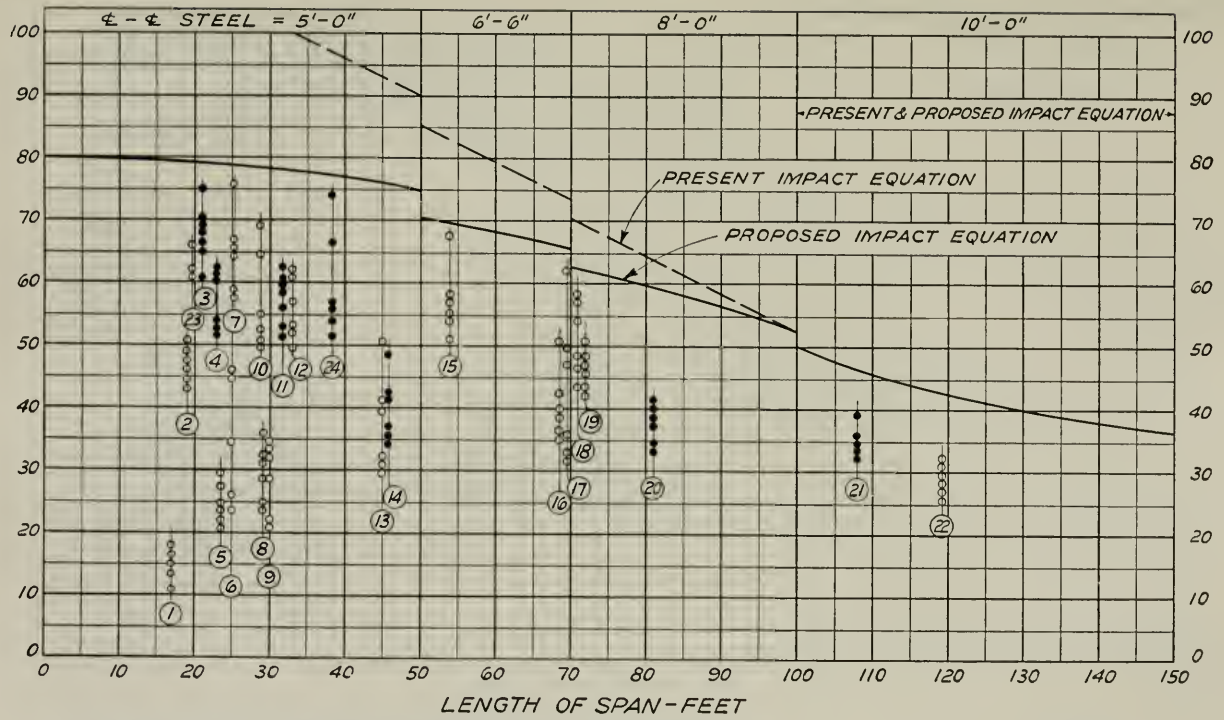
The total impacts or the percentage increase in the maximum stresses over the static stresses in the beam and girder spans under rolling equipment producing hammer blows are shown in Fig. 1. The total impact values plotted on this diagram are the six highest recorded values for each span and were selected from a total of about 1900 test runs over these spans. It can be seen that the total impact values are appreciably lower than those obtained from the present impact equation, and for this reason the committee recommends a lower impact allowance for beam and girder spans up to 100 ft. in length.

The total impacts in the truss spans under rolling equipment having hammer blow are shown in Fig. 2. The total impact values shown on this diagram were recorded in the individual member of trusses. Since impact values for long span trusses have not yet been obtained by electromagnetic strain gages, certain values, obtained in 1914 by the Subcommittee of Impact, which are free from instrumental errors, have been used. The fact that the impact obtained from the earlier test on a shorter truss agrees with recent tests on trusses of similar length, justifies the use of data from the earlier tests for the longer length trusses in the determination of the impactc urve. It was found that the impacts in these web and chord members as recorded by the electromagnetic strain gages, as well as the 1914 extensometers, are greater than those indicated by deflection readings. The same fact is borne out by the British impact tests in 1928 and

TABLE I
LIST OF TEST BRIDGES

SPAN NUMBER	RAILROAD	SPAN C. TO C. BEARINGS	TYPE OF SPAN	TYPE OF FLOOR	C. TO C. OF STEEL	NUMBER OF BEAMS PER TRACK
** 1	T. T. R. R.	17'-0"	FLOOR BEAM OF 250' THRU TRUSS	OPEN FLOOR	29'-1½" PANELS	—
* 2	A. T. & S. F. RY.	19'-0"	I-BEAMS	" "	4'-10½"	4-BEAMS
* 3	"	21'-0"	" "	TIMBER BALLASTED	4'-11½"	6- "
* 4	C. B. & Q. R. R.	23'-0"	D. P. G.	"	7'-0"	2-GIRDERS
** 5	T. T. R. R.	23'-8"	STRINGERS OF 142' DECK TRUSS	OPEN FLOOR	7'-0"	2- "
6	D. T. & I. R. R.	25'-0"	STRINGERS OF 150' DECK TRUSS	" "	6'-6"	2- "
* 7	C. & N. W. RY.	25'-2"	D. P. G.	" "	5'-0"	4-GIRDERS
** 8	T. T. R. R.	29'-1½"	STRINGERS OF 250' THRU TRUSS	" "	7'-0"	2-GIRDERS
9	D. T. & I. R. R.	30'-0"	D. P. G.	" "	6'-6"	2- "
* 10	C. B. & Q. R. R.	28'-8"	D. P. G.	" "	7'-0"	2- "
* 11	C. & N. W. RY.	31'-8"	D. P. G.	CONCRETE BALLASTED	5'-0"	4-GIRDERS
* 12	I. C. R. R.	33'-0"	W. F BEAMS	OPEN FLOOR	5'-0"	4-BEAMS
13	D. T. & I. R. R.	45'-0"	D. P. G.	" "	6'-6"	2-GIRDERS
14	C. M. ST. P. & P. R. R.	45'-8¾"	D. P. G.	TIMBER BALLASTED	8'-0"	2- "
† 15	P. R. R.	54'-0"	D. P. G.	TIMBER OPEN	5'-0"	2- "
16	C. & N. W. RY.	68'-5¼"	D. P. G.	OPEN FLOOR	8'-0"	2- "
17	"	"	D. P. G.	" "	"	2- "
18	"	70'-10"	D. P. G.	" "	6'-6"	2- "
19	"	"	"	" "	"	2- "
†† 20	P. R. R.	81'-0"	"	POURED IN PLACE CONC. BALLAST'D.	7'-0"	2- "
21	C. M. ST. P. & P. R. R.	108'-0"	T. P. G.	TIMBER BALLASTED	19'-2"	2- "
† 22	P. R. R.	119'-3"	D. P. G.	OPEN FLOOR	8'-0"	2- "
23	C. M. ST. P. & P. R. R.	PANELS 20'-4¼"	FLOOR BEAM HANGERS FOR 160' TRUSS	" "	17'-6¼" C. TO C. TRUSSES	—
24	I. C. R. R.	38'-3"	D. P. G.	CONCRETE BALLASTED	7'-0"	2-GIRDERS
25	C. B. & Q. R. R.	129'-6"	T. T.	OPEN FLOOR	15'-8"	2-TRUSSES
26	D. T. & I. R. R.	136'-9"	T. T	" "	16'-2"	2- "
** 27	T. T. R. R.	142'-0"	D. T	" "	15'-0"	2- "
28	D. T. & I. R. R.	150'-0"	D. T.	" "	17'-0"	2- "
29	C. M. ST. P. & P. R. R.	160'-0"	T. T.	" "	17'-6¼"	2- "

* THE RESULTS OF THESE TESTS PUBLISHED IN AREA PROCEEDINGS, VOL. 46, 1945.
** THE RESULTS OF THESE TESTS PUBLISHED IN AREA BULLETIN 468, SEPTEMBER-OCTOBER 1947.
† THESE TESTS MADE BY THE PENNSYLVANIA RAILROAD AND THE RESULTS PUBLISHED IN AREA PROCEEDINGS, VOL. 42, 1941.
†† THESE TESTS MADE BY THE PENNSYLVANIA RAILROAD AND THE RESULTS PUBLISHED IN AREA PROCEEDINGS, VOL. 45, 1944.


℄ - ℄ STEEL = 5'-0"
6'-6"
8'-0"
10'-0"
PRESENT & PROPOSED IMPACT EQUATION
PRESENT IMPACT EQUATION
PROPOSED IMPACT EQUATION
TOTAL IMPACT
PERCENT OF RECORDED STATIC STRESS
LENGTH OF SPAN - FEET
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
0 10 20 30 40 50 60 70 80 90 100

NOTE: ONLY THE SIX HIGHEST RECORDED VALUES ARE PLOTTED.
THE REMAINING VALUES ARE LOWER AND ARE NOT PLOTTED.

SYMBOLS: ○ OPEN FLOOR BRIDGES
● BALLASTED FLOOR BRIDGES

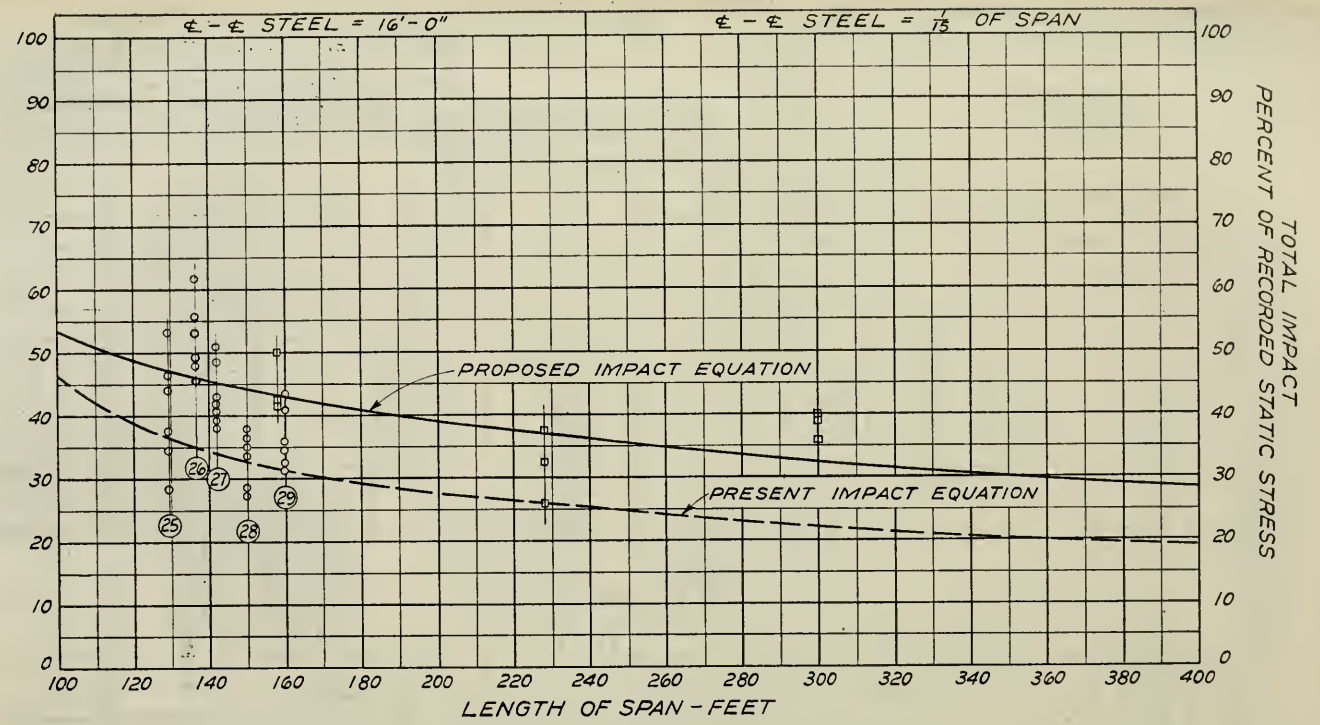
PROPOSED IMPACT EQUATION:

ROLL EFFECT: SAME AS ARTICLE 206(a)

VERTICAL EFFECT: { FOR "L" LESS THAN 100 FT. = $60 - \frac{L^2}{500}$
FOR "L" 100 FT. OR MORE, SAME AS ARTICLE 206(b)

FIG. 1

TOTAL IMPACT
IN
BEAM AND GIRDER SPANS
ROLLING EQUIPMENT HAVING HAMMER BLOW

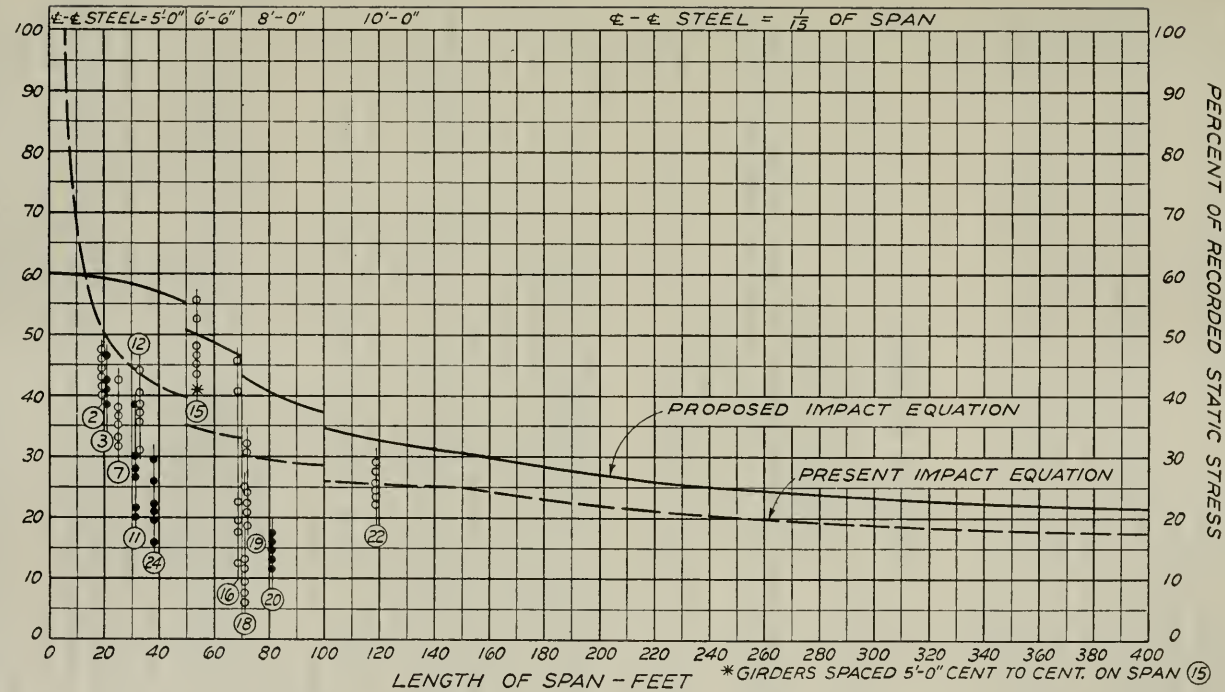


NOTE: ONLY THE SIX HIGHEST RECORDED VALUES ARE PLOTTED.
THE REMAINING VALUES ARE LOWER AND ARE NOT PLOTTED.

SYMBOLS: ○ RECENT TESTS BY AAR
□ TESTS BY SUB-COMMITTEE ON IMPACT – AREA 1914

PROPOSED IMPACT EQUATION:
ROLL EFFECT: SAME AS ARTICLE 206(a)
VERTICAL EFFECT: $\frac{4000}{L+25}+15$

FIG. 2
TOTAL IMPACT
IN
TRUSS SPANS
ROLLING EQUIPMENT HAVING HAMMER BLOW


℄-℄ STEEL = 5'-0" 6'-6" 8'-0" 10'-0"
℄ - ℄ STEEL = 1/15 OF SPAN
TOTAL IMPACT PERCENT OF RECORDED STATIC STRESS
PROPOSED IMPACT EQUATION
PRESENT IMPACT EQUATION
LENGTH OF SPAN - FEET
*GIRDERS SPACED 5'-0" CENT TO CENT. ON SPAN (15)

NOTE: ONLY THE SIX HIGHEST RECORDED VALUES ARE PLOTTED. THE REMAINING VALUES ARE LOWER AND ARE NOT PLOTTED

SYMBOLS: ○ OPEN FLOOR BRIDGES
● BALLASTED FLOOR BRIDGES

PROPOSED IMPACT EQUATION.

ROLL EFFECT: SAME AS ARTICLE 206(a)

VERTICAL EFFECT: FOR "L" LESS THAN 80 FT. = $40 - \frac{3L^2}{1600}$

FOR "L" 80 FT. OR MORE = $\frac{600}{L-30} + 16$

FIG. 3

TOTAL IMPACT

IN

BEAM, GIRDER AND TRUSS SPANS

ROLLING EQUIPMENT WITHOUT HAMMER BLOW

the bridge oscillator test reported in AREA Bulletin 467. Since the present impact equation is based upon deflection readings, it is obvious that the total recorded impacts in the individual members are greater than provided by the present equation. For these reasons, your committee recommends an increase in the impact allowance for trusses even though based on limited data.

The total impacts in beam, girder and truss spans under rolling equipment without hammer blow are shown in Fig. 3. It can be seen that the total recorded impacts in the girder spans are above the present impact allowance. The committee therefore recommends an impact allowance which includes the recorded values on the beam and girder spans. The committee also favors an increase in the impact allowance for truss spans to compensate for the difference between the impact in the individual truss members and the deflection impacts.

Report on Assignment 2

Specifications for Fusion Welding and Gas Cutting for Steel Structures

Collaborating with ASTM Committee A-1 on Steel, and the American Welding Society Conference Committee on Bridges

F. J. Pitcher (chairman, subcommittee), R. T. Blewitt, R. N. Brodie, A. W. Carpenter, C. H. Chapin, O. E. Hager, Jonathan Jones, C. T. G. Looney, N. W. Morgan, C. T. Morris, C. E. Sloan, H. C. Tammen, R. A. Van Ness, C. E. Webb, H. T. Welty, A. R. Wilson, W. M. Wilson.

This is a final report submitted as information, and includes recommended revision of the section of the Manual on Fusion Welding, page 15–133.

Since 1935 your committee has considered fusion welding and gas cutting for steel structures. A report on the application of fusion welding to steel structures is contained in the Proceedings, Vol. 38, 1937, pages 302 to 307, incl. In 1938, the Association, on the recommendation of your committee, approved the use of the American Welding Society's 1936 Specifications for Design, Construction, Alteration and Repair of Highway and Railway Bridges by Fusion Welding, pending further consideration by the committee. In 1943, the Association modified reference to these specifications adopted by the American Welding Society under the title Specifications for Welded Highway and Railway Bridges; Design, Construction and Repair, when welding is permitted, pending further consideration.

During this time, and subsequently, five members of your committee have served on the AWS Conference Committee on Welded Bridges, which prepared the Standard Specifications for Welded Highway and Railway Bridges; Design, Construction and Repair, published in 1947 by the American Welding Society.

The new specifications incorporate the results of research, to which the Association of American Railroads contributed liberally. At the present time the specifications represent the latest information on welded bridge design based on research and welding experience. Your committee recognized this when, at the 1947 annual meeting, it asked for and obtained revision of article 501 of the AREA Specifications of Steel Railway Bridges by adding:

> Where permitted, welding shall conform to the current AWS Specifications for Welded Highway and Railway Bridges.

This addition to the Specifications for Steel Railway Bridges permits the railroad bridge engineer to employ welding to the extent which he desires.

The art of welding for the railroad bridge engineer is still in a somewhat fluid state, since additional knowledge is needed to overcome the effect of impact to welded steel embrittled by cold; to improve the technique of fillet welding in order to increase the fatigue strength of welded members; and to avoid the damage done to the base metal by intense local heating, as yet imperfectly understood by non-metallurgists. These are some of the unsolved problems which confront a bridge engineer in choosing to employ welding.

Furthermore, the fact that failure of a weld occurs rapidly rather than progressively and that the human equation in field welding may lead to unsatisfactory weldments, affords little comfort when considering the safety of a welded structure with regard to railroad traffic.

While it is true that material savings in metal by welding can be obtained in details and connections, it does not follow that the savings in metal for an entire bridge afford economic justification for welding in view of the many elements involved in fabrication.

These are some of the reasons which have kept the use of welding largely confined to the repair and strengthening of existing railway bridges.

However, your committee recommends revision of the section of the Manual on Fusion Welding, page 15–133, to read as follows:

FUSION WELDING
1948

Specifications for Welded Highway and Railway Bridges—Design, Construction and Repair.

When welding is permitted, it is recommended that the current specifications adopted under the title above by the American Welding Society be used.

Your committee further recommends continuing collaboration with the American Welding Society by maintaining its membership on the AWS Conference Committee on Welded Bridges.

Report on Assignment 5

Design of Bridge Details

G. L. Staley (chairman, subcommittee), P. E. Adams, H. A. Balke, C. H. Chapin, R. P. Davis, A. M. Gruber, G. V. Guerin, Jr., Shortridge Hardesty, R. A. Kane, M. B. Lagaard, R. W. Mabe, D. V. Messman, N. M. Newmark, A. G. Rankin, J. F. Salmon, R. A. Van Ness, J. E. Yewell, W. L. Young.

Your committee submits the following report of tests on a bridge rocker assembly as information. The report was occasioned by a controversy as to the application of article 445 of the Specifications for Steel Railway Bridges in regard to the thickness of the base plate for a bridge rocker assembly.

Since a bridge rocker transmits its load to the base plate through a line bearing, the requirement that the thickness of the base plate be not less than half the difference in width between the top and bottom bearing surfaces necessitates the use of a plate,

slab or casting having a thickness not less than half the total width, which is uneconomical. Structurally, considering the slab as a cantilever, no such thickness is needed for the base slab.

However, the test did develop that there is need for further research to determine for bridge rocker assemblies a ratio of thickness to width of the base slab, which will assure the application of suitable bearing pressure to the masonry.

Report of Bridge Rocker Shoe Assembly Test

By M. B. Lagaard

Associate Professor of Civil Engineering, Northwestern Technological Institute

The purpose of this test was to study the distribution of pressure exerted by a rocker shoe slab on a concrete pier, or abutment seat, and to measure the corresponding stress and deflection in the slab with a view toward gaining more information for the purpose of design.

Method

The method, in brief, consisted of measuring the pressure on the slab of a rocker shoe assembly by means of steel loading blocks covering essentially the entire area of the slab, and determining the stresses and deflections in the slab by electrical strain gages and an Ames dial, respectively. The bearing of the slab on a concrete seat was secured by placing the assembly on a thin layer of cement grout.

To avoid some of the problems of model analysis, a full size rocker unit was used for the test. This consisted of a base slab 1 ft. 10 in. wide, 3 ft. 3 in. long, and 3 in. thick, a rocker 2 ft. long, on the line bearing with a radius of 16¾ in. and a cap slab 1 ft. 6¼ in. long, by 2 ft. wide. (See Figs. 1 and 2.)

In order to approximate conditions expected in actual bridges, a somewhat massive concrete base was built. This base was 30 in. wide, 47 in. long, and 27½ in. high. The concrete for this base was designed to produce an ultimate compressive strength of 3000 psi., but because of the high quality of the cement used, the strength proved to be 4000 psi. at the time tests on the rocker assembly were made.

The method of measuring the pressures on the slab, consisted of using the pedestal type of loading block 2 in. square at the top and bottom, with a reduced section, 1 in. square in the middle. The total height of the block was 3 in. The block was machined from a solid 2-in. hot-rolled steel bar to exact size and surface ground at the top and bottom. Strains in the blocks were measured by taking readings with SR–4 strain gages on both sides of the middle section of the block which, because of its reduced size, deformed sufficiently to permit accurate measurements to be taken. Each block was calibrated individually to determine the load-strain relationship, but the curves were so close to that obtained by assuming a 30 million modulus, that this figure was finally adopted for the reduction of the data.

The blocks were glued to the underside of the rocker shoe base slab with Duco cement and were arranged in rows with sufficient space between certain rows to permit attachment of the strain gages to the underside of the slab and allow the wires attached to them to be brought out from under the slab for connection to the stress strain recorder (See Fig. 3).

The bearing blocks and base slab were turned over by means of a cradle (See Fig. 4) and the blocks set direct on the freshly mixed grout covering the concrete base

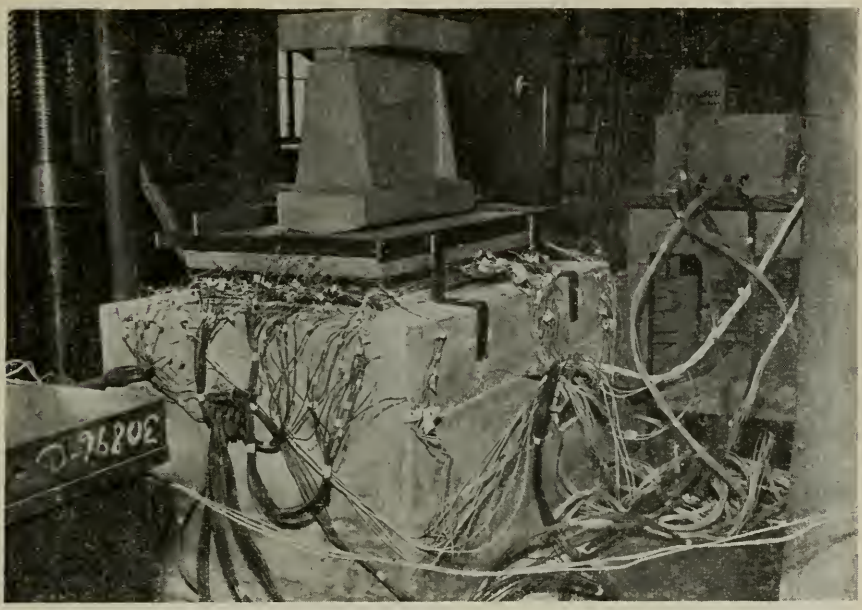


Fig. 1.—Expansion Rocker Mounted on Base Slab. Wires Run from SR–4 Strain Gages to Multiple Switch and Then to Strain Gage Indicator.

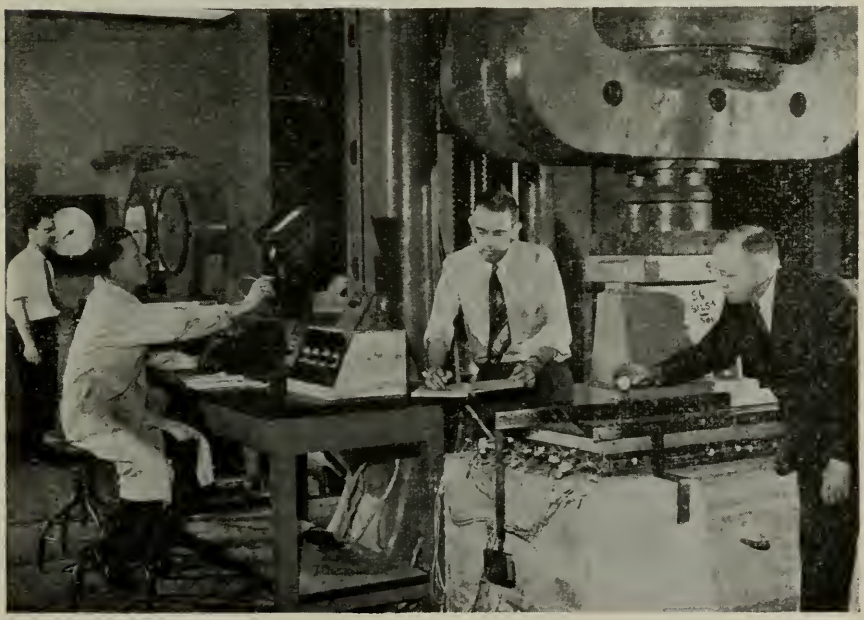


Fig. 2.—Strains and Deflections Being Taken with Load Applied by Testing Machine.

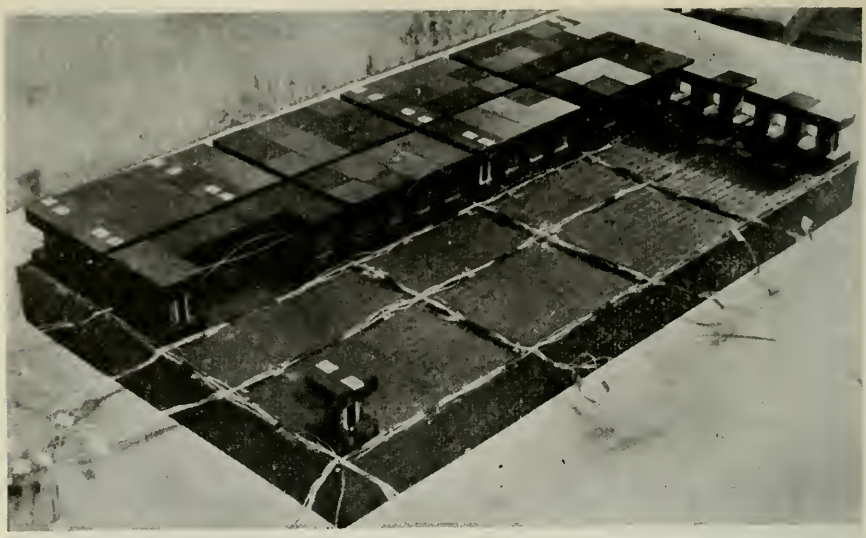


Fig. 3.—Part of Bearing Blocks Mounted on Under Side of Base Slab.

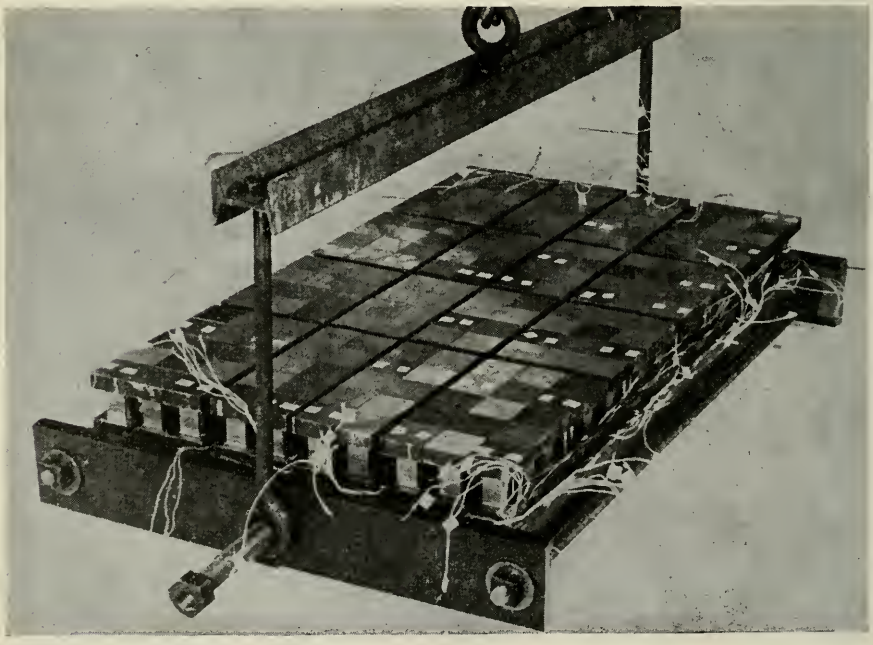


Fig. 4.—Method of Turning Over Base Slab and Bearing Blocks.

over this area. The rocker and cap slab were placed in position on the base slab to complete the assembly, after which the head of the testing machine was lowered and the initial load of 800 lb. was applied. Test readings were started after the grout had acquired its 24-hour strength.

The transverse and longitudinal stresses in the base slab were measured by means of SR–4 wire gages and a static stress recorder. Measurements were taken on the underside of the slab along the quarter points and center lines in both a horizontal and transverse direction.

Transverse stresses were also measured at one point along the top of the slab just beyond the end of the rocker. Fig. 5 shows the position of the loading blocks on which readings were taken. Fig. 6 shows the location of the numbered gage lines on the underside, and of the lettered gage lines on the top of the slab. In all, 122 strain readings and 48 deflection readings were taken at each load.

Vertical deflections were measured by a portable deflectometer, capable of measuring to an estimated accuracy of 1/1000th of an inch, (See Fig. 7).

Loads

Three separate tests were made. Test No. 1 was made with the rocker vertical. The initial load was 800 lb. and additional increments of 100,000 lb. were applied, up to a maximum of 515,000 lb. This was 43 percent in excess of the design load. A complete set of strain and deflection readings was taken at each increment load in all of the tests.

Test No. 2 was made with the rocker tilted 1 in. off center at the top, with the same maximum load as in test No. 1, but in this case it was applied, without increments.

In test No. 3, the loading blocks were removed and the slab was placed directly on a ⅛-in. layer of lummite cement grout on the concrete base. The load in this case was applied vertically with increments up to the design load of 360,000 lb. Inspection of the effectiveness of the grout, after the first two tests were completed, revealed the fact that the grout covered the bearing area uniformly throughout. In test No. 3, however, a uniform bearing was not secured and the results were correspondingly erratic. Enough information was obtained however, to verify the accuracy of the loading block method of measuring pressures, which was the purpose of this particular test.

Results

Results of maximum loads only, are shown in the graphs given in this report, with the exception of test No. 1, where in addition, the test for the design load was interpolated from the increment test results. Fig. 8 shows the transverse and longitudinal distribution of pressures of the slab on the concrete base, for the vertical design load of 360,000 lb. These results were interpolated from the increment readings. Fig. 9 shows the corresponding transverse and longitudinal stresses on the underside of the slab for this load. Fig. 10 gives the same information for the deflections.

In Figs. 11, 12 and 13, the pressures, stresses and deflections for a total of 515,000 lb. load are given. In Figs. 14, 15 and 16, the same information is given for a maximum load of 515,000 lb. with the rocker tilted 1 in. off from the vertical position. Fig. 17 shows the differences in the stresses at the surface along the lettered gage lines for tests Nos. 1 and 3 given for sake of comparison of the stress distribution with, and without the loading blocks.

(text continued on page 229)

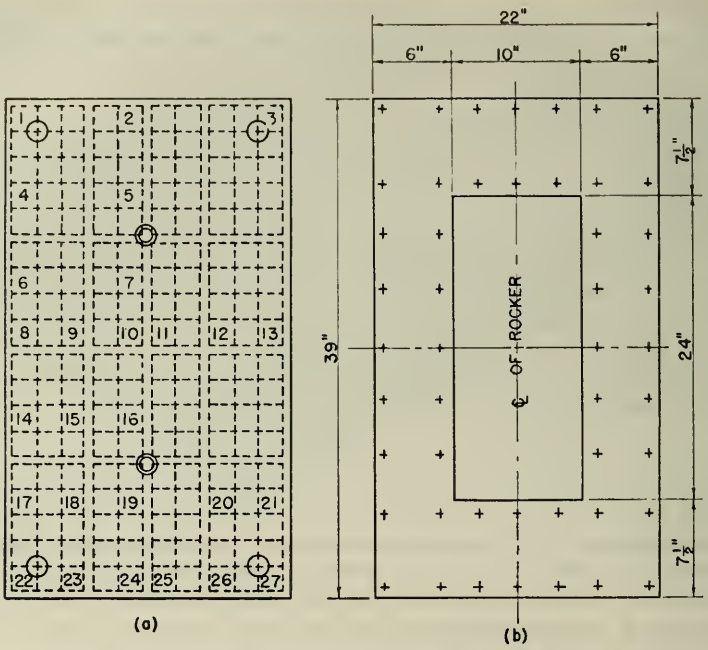


Fig. 5.—(a) Location of Loading Blocks on Which Measurements were Taken and (b) Points on Top of Slab at Which Deflections Were Measured.

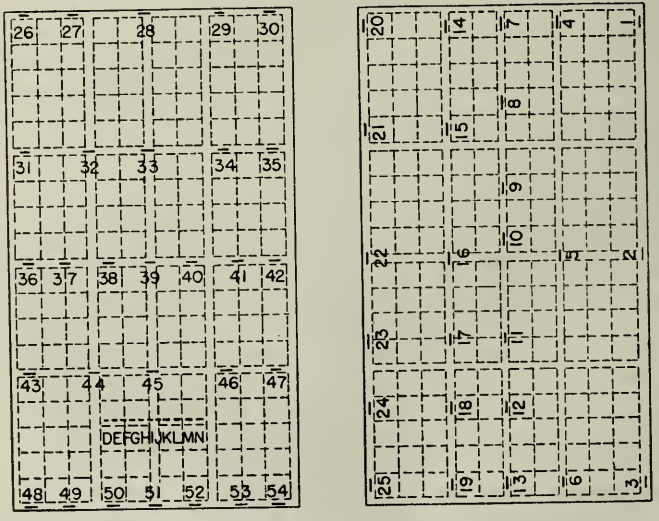


Fig. 6.—Location of Longitudinal and Transverse Gage Lines on Bottom and Top of Rocker Shoe Base Slab.

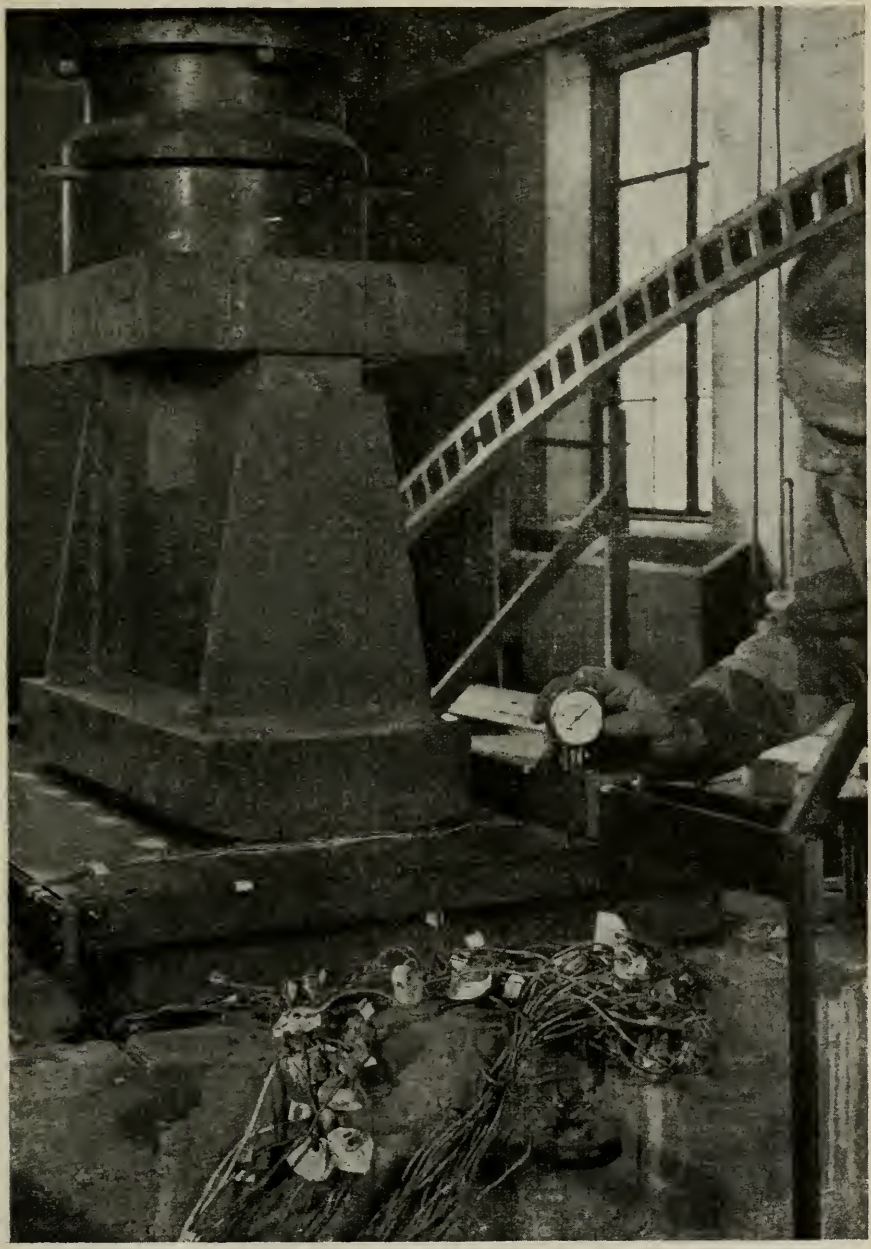
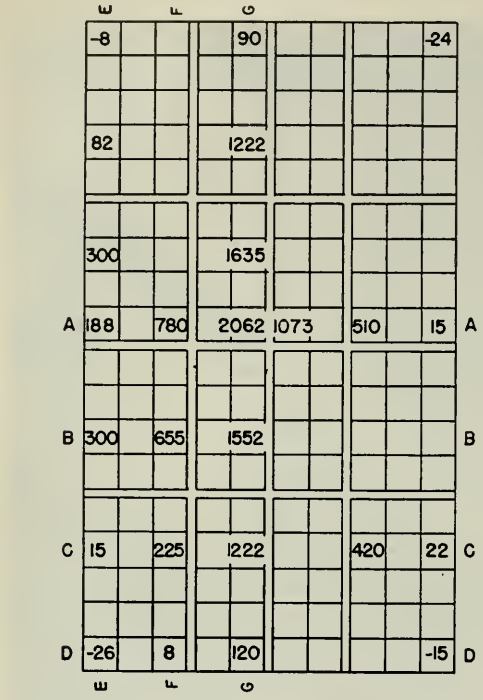
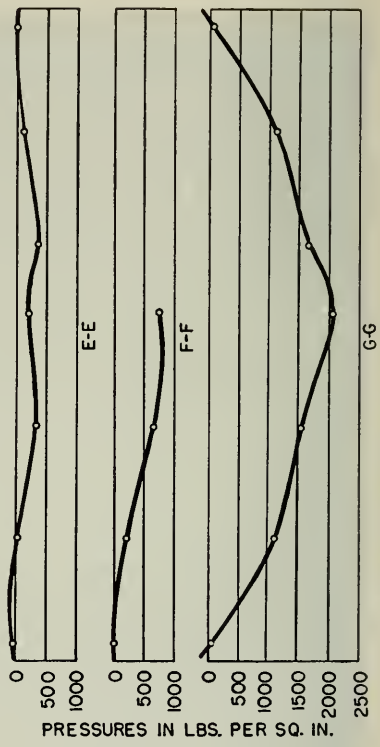
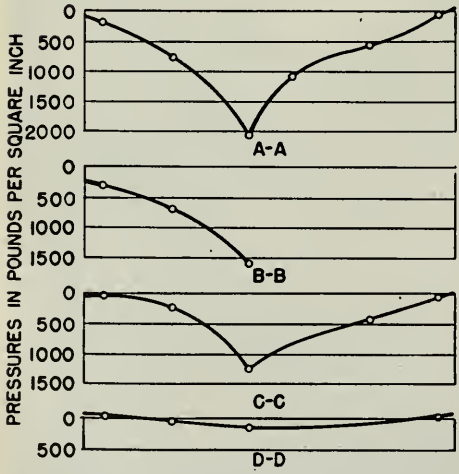


Fig. 7.—Measuring Deflection of the Rocker Shoe Base Slab.





Longitudinal distribution of pressures on concrete base



Transverse distribution of pressures on concrete base

Fig. 8.—Distribution of Pressures under Rocker Shoe Base Slab for Load of 360,000 lb. (Design Load). Rocker in Vertical Position.

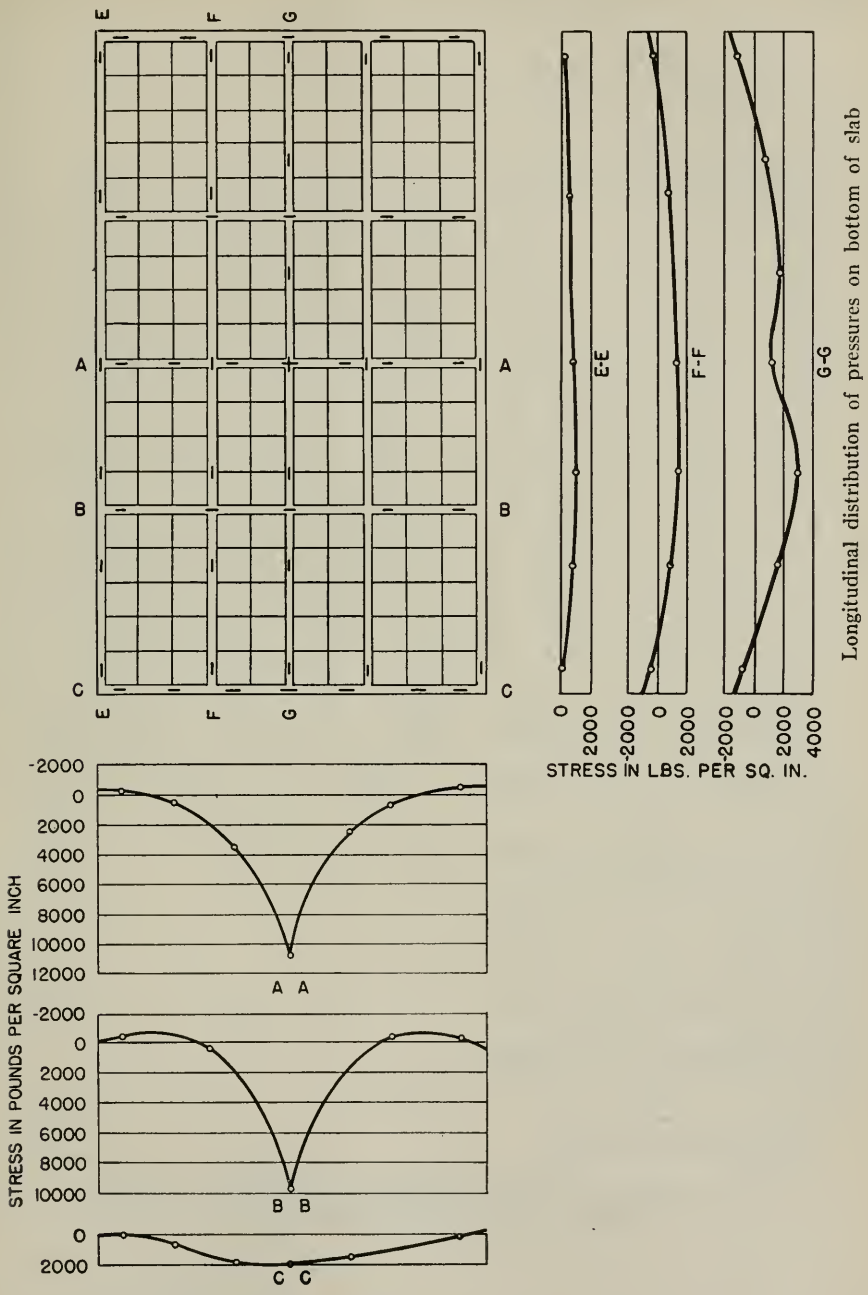


Fig. 9.—Distribution of Stresses on Bottom of Rocker Shoe Base Slab for Load of 360,000 lb. (Design Load). Rocker in Vertical Position.

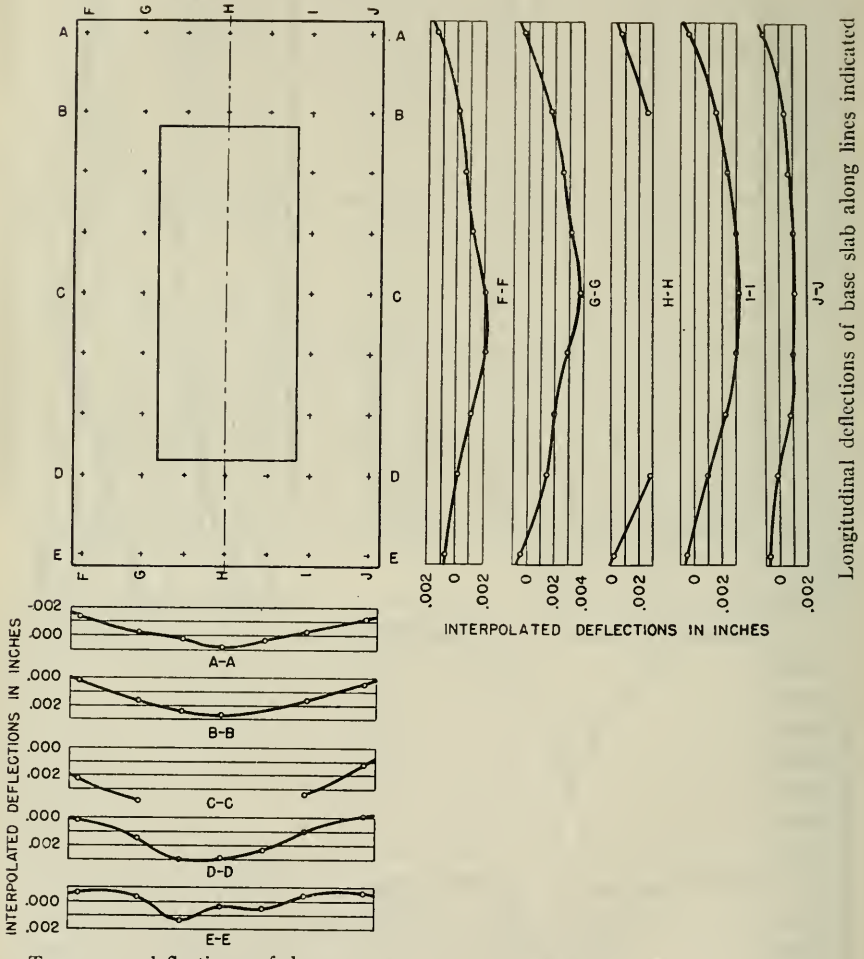


Fig. 10.—Deflections of Rocker Shoe Base Slab for Load of 360,000 lb. (Design Load). Rocker in Vertical Position.

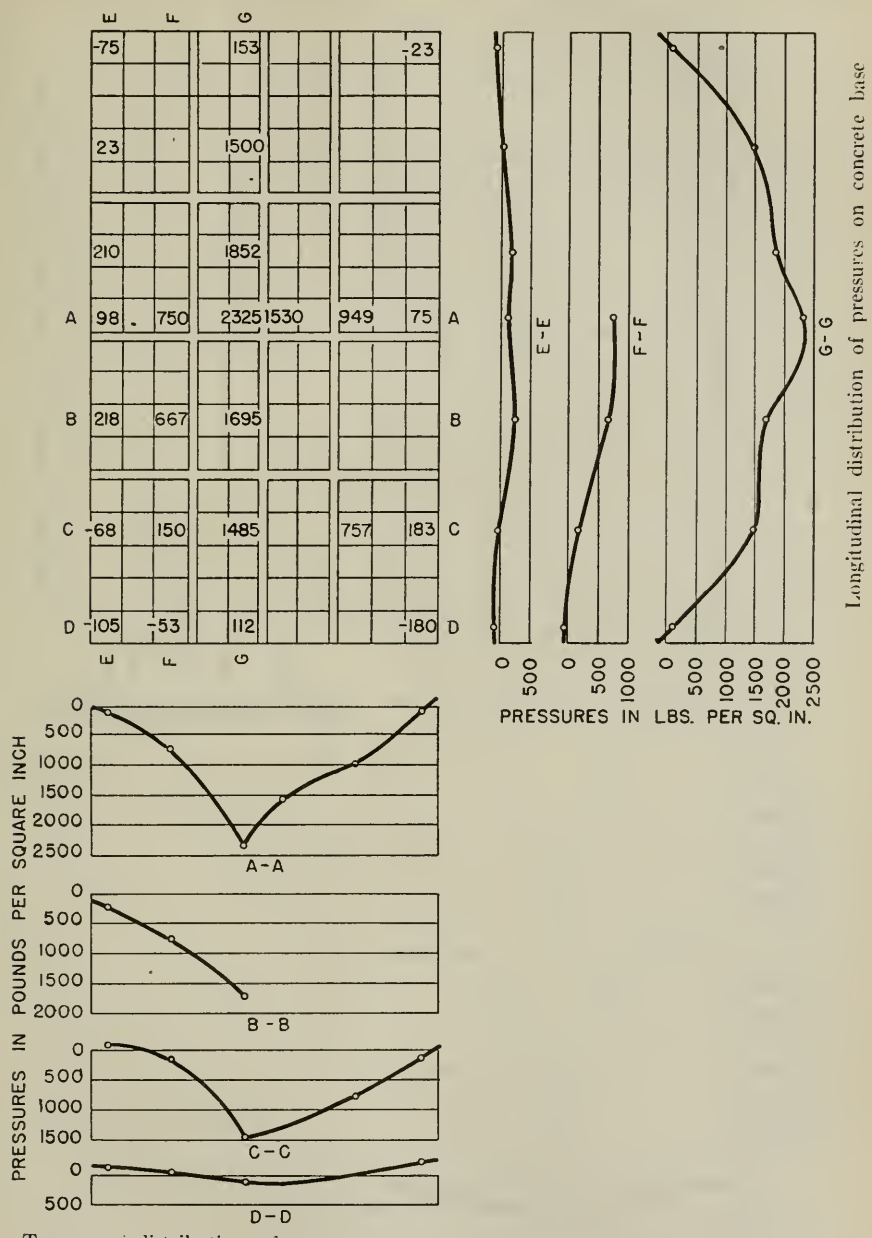

E F G
-75 153 -23
23 1500
210 1852
A 98 750 2325 1530 949 75 A
B 218 667 1695 B
C -68 150 1485 757 183 C
D -105 -53 112 -180 D
E F G
E-E
F-F
G-G
0 500 0 500 1000 0 500 1000 1500 2000 2500
PRESSURES IN LBS. PER SQ. IN.
Longitudinal distribution of pressures on concrete base
PRESSURES IN POUNDS PER SQUARE INCH
0 500 1000 1500 2000 2500
A-A
0 500 1000 1500 2000
B-B
0 500 1000 1500
C-C
0 500
D-D
Transverse distribution of pressures on concrete base

Fig. 11.—Distribution of Pressures under Rocker Shoe Base Slab for Load of 515.000 lb.; Rocker in Vertical Position.

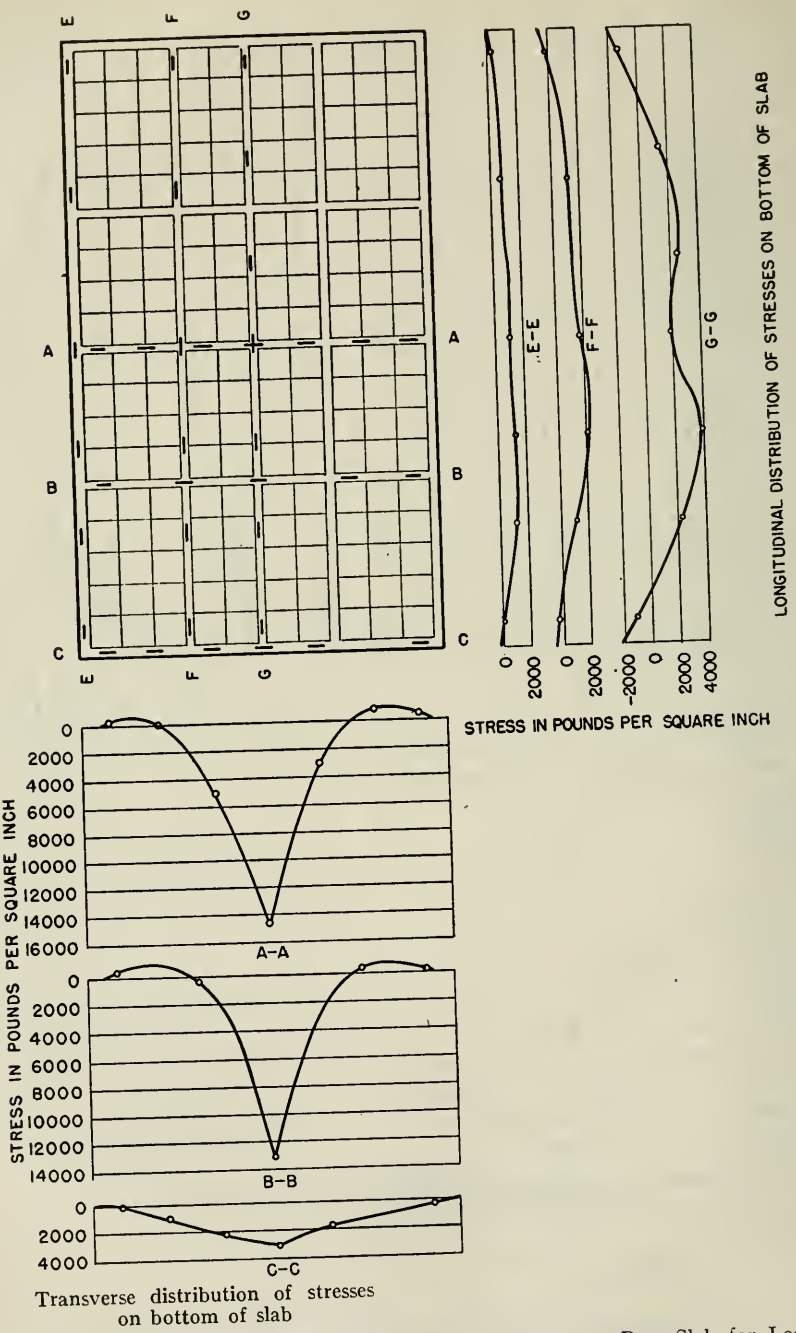


Fig. 12.—Distribution of Stresses on Bottom of Rocker Shoe Base Slab for Load of 515,000 lb.; Rocker in Vertical Position.

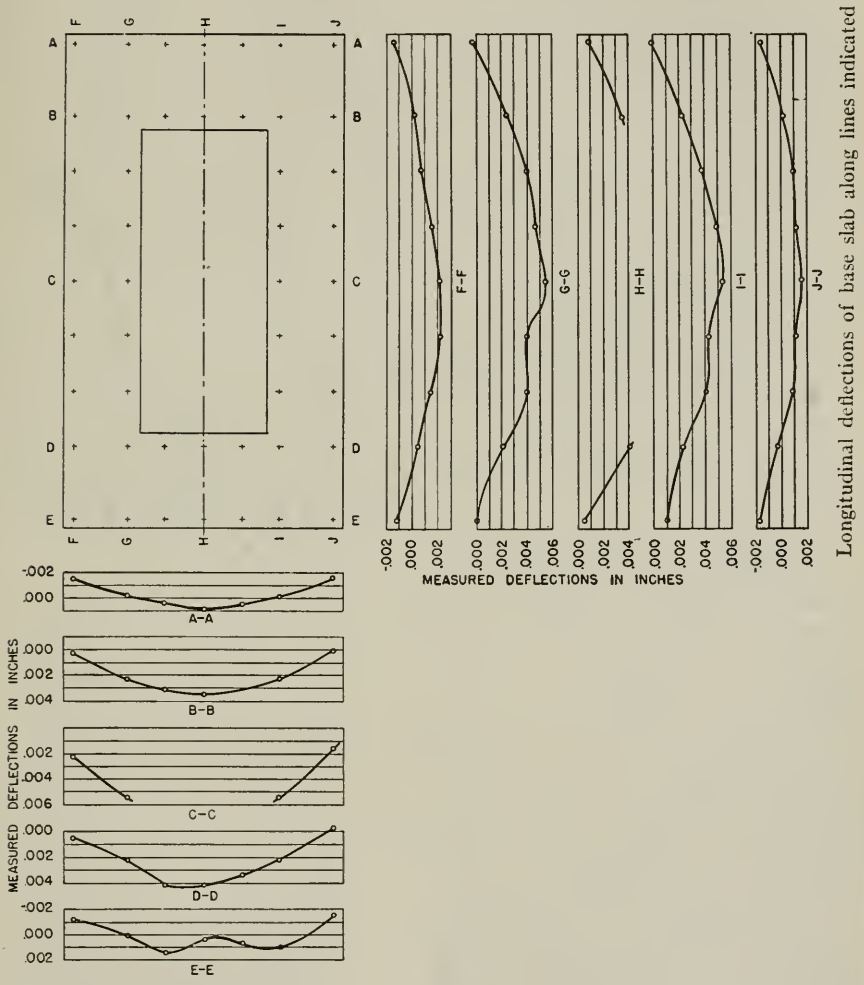


Fig. 13.—Deflection of Rocker Shoe Base Slab for Load of 515,000 lb. Rocker in Vertical Position.

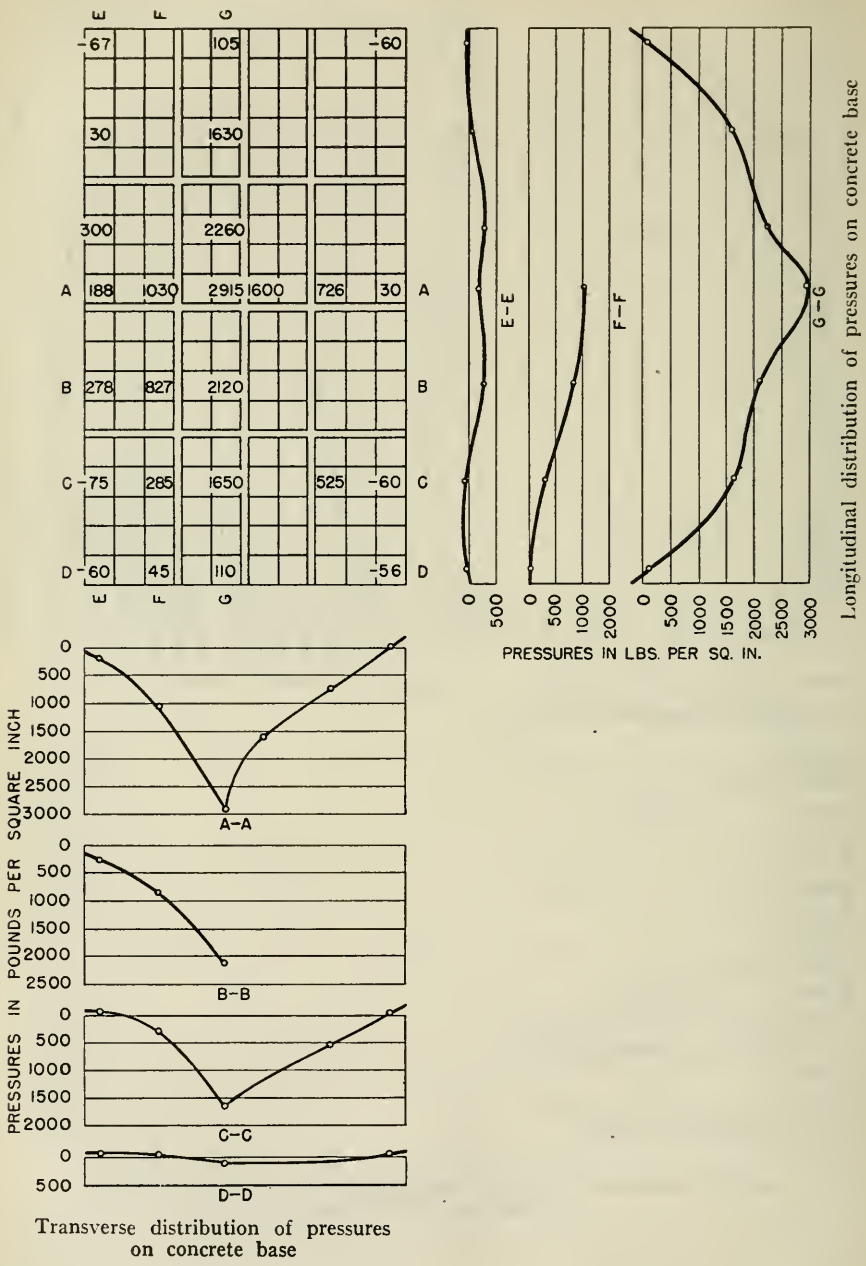


Fig. 14.—Distribution of Pressures under Rocker Shoe Base Slab for Load of 515.000 lb. Rocker Tilted 1 in. to the Right.

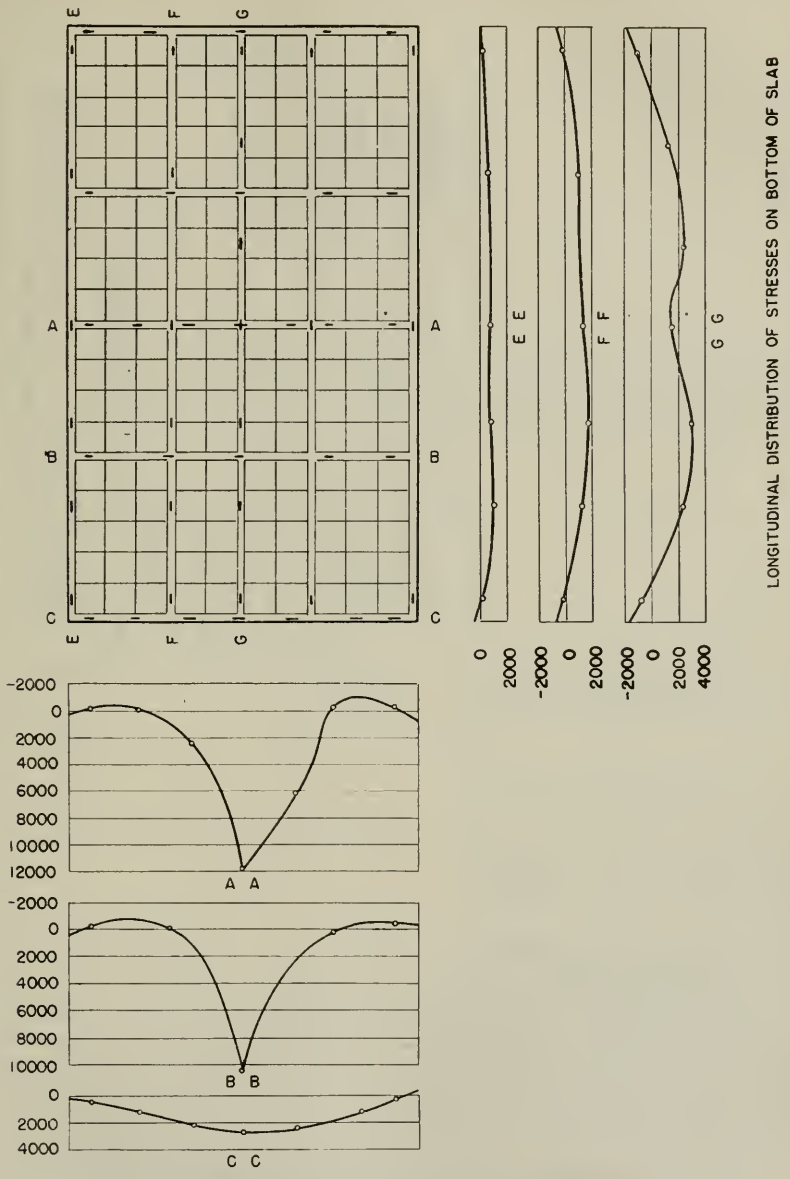


Fig. 15.—Distribution of Stresses on Bottom of Rocker Shoe Base Slab for Load of 515,000 lb.; Rocker Tilted 1 in. to the Right.

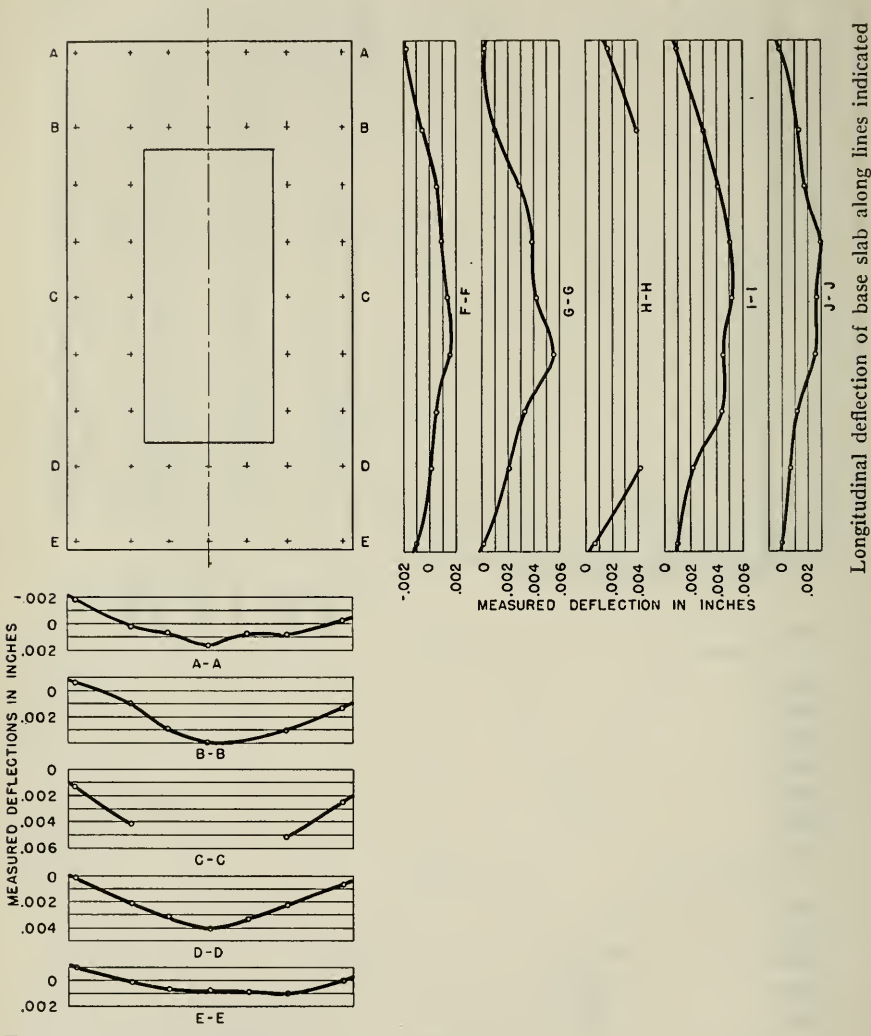


Fig. 16.—Deflection of Rocker Shoe Base Slab for Load of 515,000 lb. Rocker Tilted 1 in. to the Right.

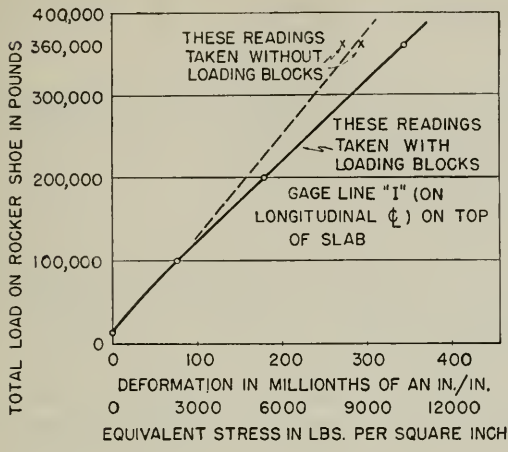
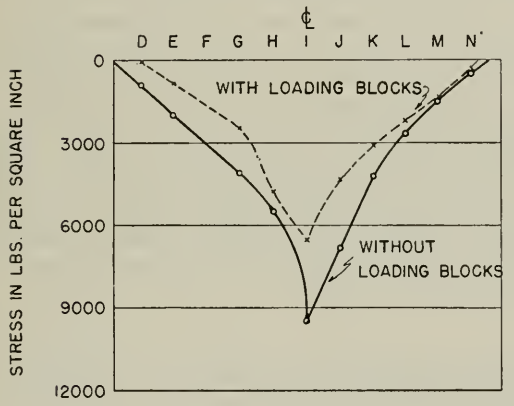

400,000
360,000
300,000
200,000
100,000
0
TOTAL LOAD ON ROCKER SHOE IN POUNDS
THESE READINGS TAKEN WITHOUT LOADING BLOCKS
THESE READINGS TAKEN WITH LOADING BLOCKS
GAGE LINE "1" (ON LONGITUDINAL ℄) ON TOP OF SLAB
0 100 200 300 400
DEFORMATION IN MILLIONTHS OF AN IN./IN.
0 3000 6000 9000 12000
EQUIVALENT STRESS IN LBS. PER SQUARE INCH

Fig. 17.—Distribution of Transverse Stresses in Top Side of Base Slab at Edge of Shoe—With and Without Loading Blocks—Under Total Load of 360,000 lb.



(text continued from page 217)

Discussion of Results

The results of these tests indicate that for the design load, the pressure between the rocker shoe slab and the concrete base on which it rests, is not uniform, but varies from a negative value at the corners, to a maximum at the center of about five times the average. The maximum pressure for a 515,000 lb. load is slightly more than five times as great under the rocker shoe as the average. This is shown in Figs. 8 and 11. It will be seen by reference to these figures that the stress is a maximum in the blocks nearest the center of the slab where the pressure from the rocker is concentrated, and a minimum at the corner where it actually assumes a negative value. The longitudinal distribution changes gradually with a maximum pressure again occurring near the center of the slab. The transverse stresses show the same type of distribution. (See Figs. 9 and 12.) In Fig. 12 it may be seen that the maximum extreme fiber stress in bending occurs at the center of the slab; the value is 14,550 psi. It is 13,140 psi. at the quarter point. The deflection readings bear out the general reliability of the stress and

pressure measurement and indicate curling up of the corners of the slab. Some of this upward deflection may be also noted along the longitudinal center line of the rocker at the extreme edges of the slab.

With the rocker tilted forward 1 in. at the top, a noticeable change in the position of maximum pressure and stress may be seen, due to a change in the line at which the pressure is applied. The general behavior however, is in accordance with the previous findings. This is shown in Figs. 14, 15, and 16.

Summary of Conclusions

The results of these tests indicate the following: (1) The bearing pressure of the rocker shoe slab on the concrete base was not uniformly distributed, but varied from a slightly negative value at the corners to a maximum of about 2060 psi. at the center, for the design load. This is equal to about five times the calculated average value. The maximum pressure on the concrete occurred at the center of the pressure area where the concrete is confined in all directions. Since high stresses in concrete laterally restrained may occur without serious danger of failure, this condition should not be considered alarming. (2) Stresses in the base slab cannot be accurately calculated on the assumption that the slab acts as a cantilever beam under uniform bearing pressure. However, this method of calculating the base slab stresses gives values considerably higher than actually occurred, hence it is on the safe side. (3) The deflections of the base slab confirmed the readings of bearing pressure on the concrete and strains or deformations in the slab. (4) The strain gage readings on top of the slab for the tests with and without the loading blocks, confirmed the reliability of the loading block method of measuring pressure. (5) Changes in the design of the slab by reduction in the bearing area and an increase in the thickness should give lower maximum pressure on the concrete, at no greater cost. (6) Additional tests should be made to establish the proper relationship between these variables. These tests should include slabs of various dimensions as well as variable bedding methods.

Acknowledgment

The tests described in this report were conducted at the Northwestern Technological Institute, at Evanston, Ill., as part of the program of Committee 15, of which E. S. Birkenwald is chairman. The rocker assembly was fabricated by the Bethlehem Steel Company, for the Chinese Supply Commission. The rocker assembly was loaned free for use in these tests through the courtesy of Jonathan Jones, chief engineer, Fabricated Steel Construction Division, Bethlehem Steel Company, and P. C. Lee of the Chinese Supply Commission, to which the rocker shoe assembly belonged. The Association of American Railroads paid the cost of shipping the assembly from Potstown, Pa. to Evanston and return.

The contributions of Mr. Birkenwald in promoting and planning the program of the tests and in preparing the final report were greatly appreciated. Acknowledgment is also due Mr. Jones and G. L. Staley, chairman of the subcommittee on bridge details, for help in reviewing the general test program. G. M. Magee, research engineer of the Association of American Railroads, contributed greatly to the success of the test by making important suggestions regarding the test procedure as the work progressed. E. J. Ruble, structural engineer of the Association, prepared the preliminary report and contributed to the many phases of the test analysis. Professor A. D. Taylor, Monrad Rasmussen, and Robert J. Lowe contributed greatly to the work of developing and installing the equipment set-up.

Report on Assignment 6

Shortening of Eyebars to Equalize the Stress

A. B. Chapman (chairman, subcommittee), A. G. Rankin, C. H. Sandberg, G. L. Staley, J. P. Walton, A. R. Wilson, W. M. Wilson, L. T. Wyly.

Last year your committee presented as information, a preliminary report on the shortening of eyebars to equalize the stress (Proceedings, Vol. 48, 1947, pages 969 to 986, incl.). From this material recommended practice for the shortening of eyebars is now submitted as a final report of your committee with the recommendation that it be adopted and published in the Manual.

METHOD OF SHORTENING OF EYEBARS TO EQUALIZE THE STRESS

The detail of the clamp plates, rods and trammel used in the tightening of loose eyebars is shown in Fig. 1. The general procedure which shall be followed in the flame shortening of the eyebars is as follows:

1. Remove the paint from those areas where the clamp plates are to be fastened and from the 12-in. length of bar to be heated, midway between the upper and lower clamp plate areas.

2. Bolt the clamp plates to the eyebar with the V-grooves on the center line of the bar, allowing ample length of thread on the clamp rods so that the nuts will have plenty of room to turn when the eyebar is upset. Keep the nuts on the clamp rods loose as the eyebar will expand during heating.

3. Attach block and falls to inclined eyebars about 6 ft. above clamp plates to take possible sag out of the bar and to insure that no sag results after the eyebar is heated Do not put too much uplift on the bar.

4. Provide a canvass shield to protect the heated area of the eyebar when there is a strong wind.

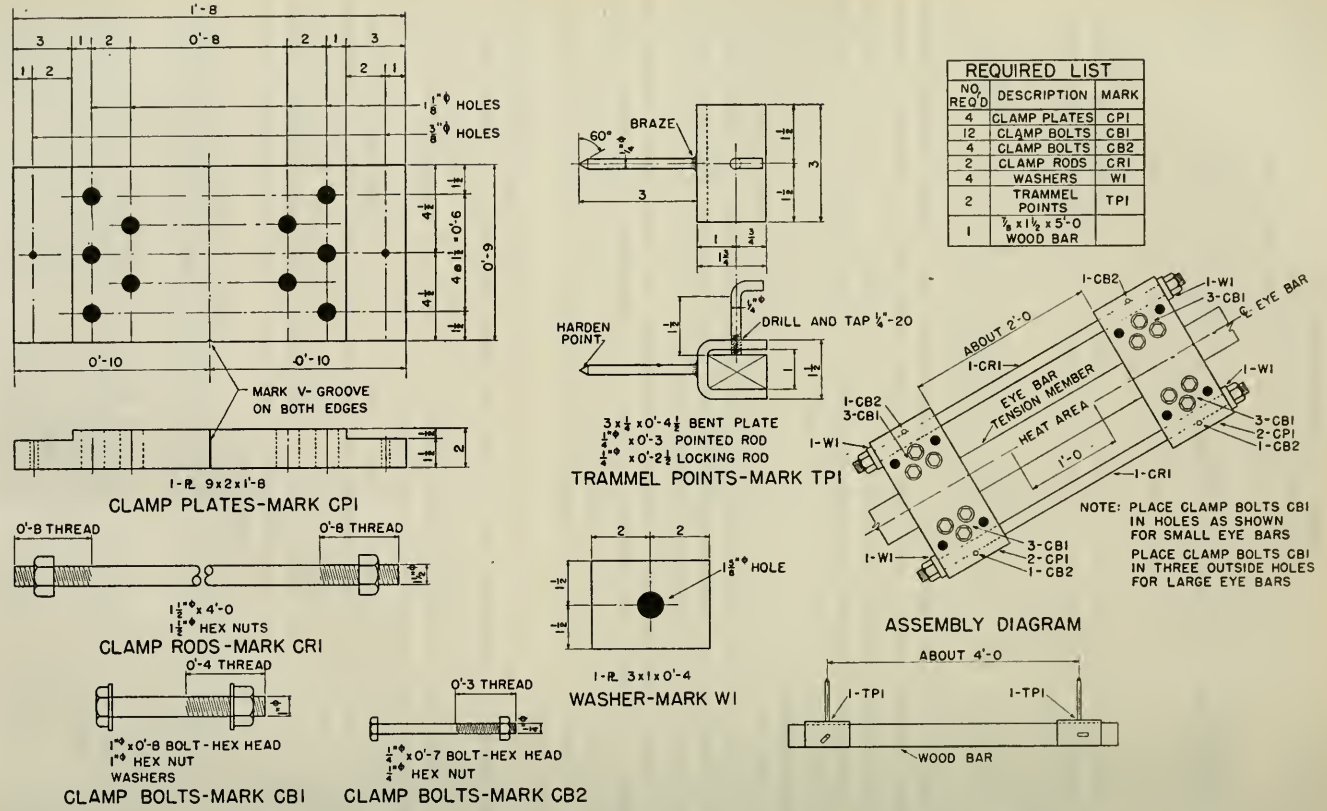
5. Measure the decrease in the length of the eyebar with trammel points by placing punch marks or scratches on the bar above and below the clamp plates before the bar is heated.

6. Check the train line-up and allow about one hour between trains for the heating, upsetting and cooling of the eyebar.

7. Heat both sides of the bar for a length of 12 in., midway between the upper and lower clamp plates, simultaneously with two torches to cherry red or a temperature of 1600 to 1800 deg. F. Apply the heat uniformly on both sides of the bar, which can be done by moving the torches in the same direction as the heating progresses. Use an Oxweld No. 150 tip, or one with equal flame, when oxygen with acetylene or other suitable gas is used for the heating medium.

8. Measure the temperature of the heated area with a pyrometer. The best results have been obtained with an Alnor Pyrocon single-point contact pyrometer registering up to 2000 deg. F.

9. When the 12-in. area is fully heated to 1600 or 1800 deg. F., tighten the nuts on the clamp rods simultaneously and the heated area will upset a very small amount. Take considerable care, especially on large eyebars, to make sure that the interior of the bar is fully heated. It is essential that the nuts on both clamp rods are tightened the same amount. By a side push on the eyebar close to the head, it can be determined if the heads are tight against the pins.



REQUIRED LIST		
NO. REQ'D	DESCRIPTION	MARK
4	CLAMP PLATES	CP1
12	CLAMP BOLTS	CB1
4	CLAMP BOLTS	CB2
2	CLAMP RODS	CR1
4	WASHERS	W1
2	TRAMMEL POINTS	TP1
1	7/8 x 1 1/2 x 5'-0 WOOD BAR	

Fig. 1.—Detail of Clamp Plates, Rods and Trammel for Tightening Loose Eyebars.

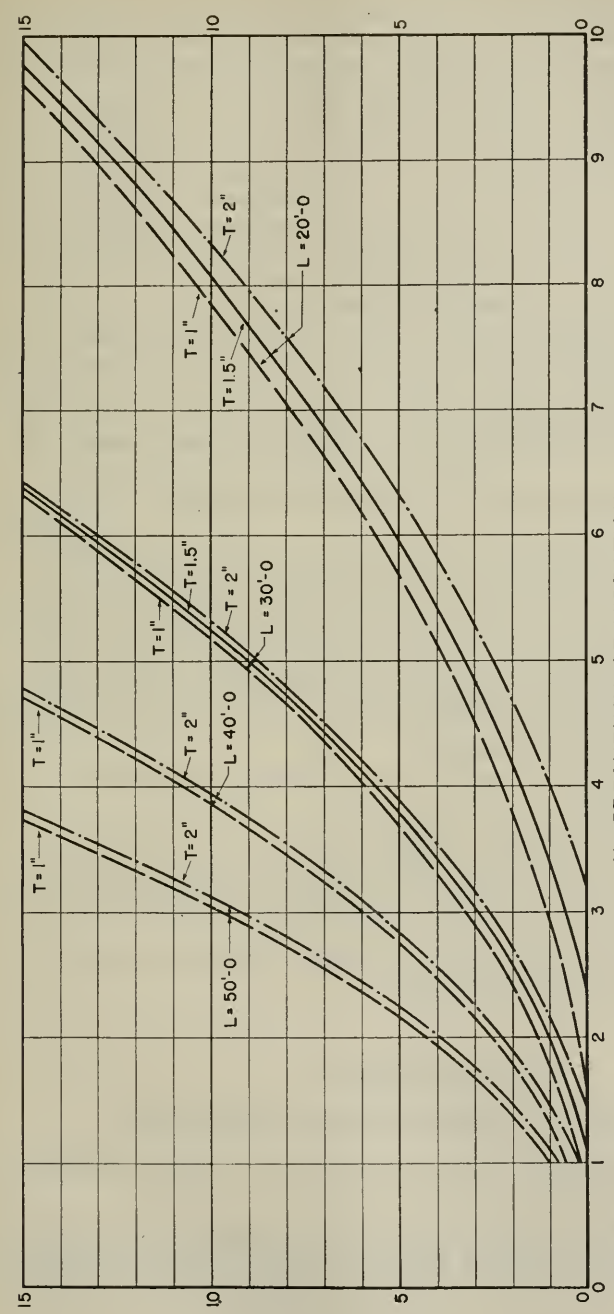

F = UNIT STRESS IN EYE BAR
KIPS PER SQUARE INCH
N = FREQUENCY OF VIBRATION
EQUATION ··· F = 0.00293 N²L² – 24,700,000(T/L)²
WHERE ····· F = UNIT STRESS IN KIPS PER SQUARE INCH
N = FREQUENCY OF VIBRATION (NUMBER OF COMPLETE OSCILLATIONS PER SECOND)
L = LENGTH OF EYE BAR IN INCHES
T = THICKNESS OF EYE BAR IN INCHES
L = 50'-0
L = 40'-0
L = 30'-0
L = 20'-0
T = 1"
T = 1.5"
T = 2"

Fig. 2.—Frequency of Vibration and Unit Stress Curves for Eyebar Tension Members with Hinged Ends.

10. The required amount of eyebar shortening, as measured by the trammel points and punch marks, may be as little as 1/32 in., or it may range up to 1¼ in. It has been found from experience that less kinking of the eyebar will result if the reduction in length is kept below ¼ in. for one heating.

11. If the eyebar shows a tendency to buckle, place a 2 or 3 ft. length of 8-in. steel channel on each side of the bar and cinch with heavy "C" clamps, striking with a maul if necessary to straighten the bar.

12. If it is desired to keep the initial or dead load stress in the eyebar low, quickly replace the No. 150 tips with No. 60 tips and keep a 3 or 4-in. length of bar in the middle of the 12 in. heated area at a temperature of 1600 to 1800 deg. F. for 3 or 4 min. This short section of heated bar allows elongation in this area while the remainder of the heated area is cooling and contracting.

If it is necessary to reduce the initial or dead load stress in an eyebar after the adjustment has been made and the eyebar has fully cooled, heat a shorter length of the eyebar to 1600 or 1800 deg. F. with the clamps still in place and the nuts on the clamp rods loose. The weight of the lower portion of the eyebar or the pull on the pins when the eyebar is hot will again lengthen it and then cooling will place a smaller initial tension in the bar.

13. The eyebar may be quenched with water when the temperature of the bar is below 1000 deg. F.

14. Traffic may be resumed over the bridge after the heated area has cooled to 300 deg. F.

15. Approximately dead load stress in the eyebar may be determined by measuring the frequency of vibration of the bar about its minor axis and then applying the results of Fig. 2.

16. The frequency of vibration of the eyebar or the number of complete oscillations per second can be measured in the following manner:

a. Remove the clamp plates and bolts.
b. Clip a sheet of paper or cardboard to a small piece of wood clamped to the edge of the eyebar.
c. Vibrate the bar by hand about its weak axis.
d. Hold a pencil on the paper or cardboard and then draw the pencil lengthwise along the eyebar for a definite interval of time, say a 10-sec. interval. The pencil will then record the number of oscillations for this interval of time.

Note: For a comprehensive discussion of the flame shortening of eyebars, see Proceedings, Vol. 48, 1947, pages 969 to 986, incl.

Report on Assignment 7

Specifications for Cold Riveted Construction

R. A. Van Ness (chairman, subcommittee), P. E. Adams, R. W. Mabe, F. M. Masters, J. F. Salmon, W. M. Wilson.

Your committee submits as information the following progress report on a program, formulated by the Research Council on Riveted and Bolted Structural Joints, which among other features of investigation is expected to develop information relative to cold driven rivets.

The sponsors of the Council are:

American Institute of Steel Construction.
American Institute of Bolt, Nut and Rivet Manufacturers.
American Society of Civil Engineers.
Association of American Railroads.
(Through Committee 15, Iron and Steel Structures, AREA)
Engineering Foundation.
Illinois State Highway Department.
Northwestern University.
University of Illinois.
United States Public Roads Administration.

The Council approved seven projects as follows:

1. Effect of bearing pressure on static and fatigue strength of hot and cold riveted joints.

2. Effect of rivet pattern on static strength of structural joints.

3. The strength of rivets in shear and combined shear and tension.

4. Fatigue strength of bolted structural joints.

5. Effect of grip upon the fatigue strength of riveted joints designed to fail in the rivets.

6. Fatigue strength of high-strength steel riveted joints.

7. The effect of rivet pattern upon the fatigue strength of structural joints.

The tests are being conducted at Northwestern University and at the University of Illinois. The degree of availability of personnel for running the tests and compiling the data will govern the time when conclusions can be drawn to formulate specifications for cold riveted construction.

Report of Committee 3—Ties

C. D. Turley, *Chairman,*
M. L. Bardill
R. S. Belcher
H. J. Bogardus
W. C. Bolin
W. H. Brameld
P. D. Brentlinger
H. F. Brown
W. J. Burton
R. E. Butler
G. B. Campbell
B. S. Converse
R. L. Cook
R. W. Cook
H. R. Duncan
T. H. Friedlin
L. E. Gingerich
B. D. Howe
E. A. Humphreys
C. E. Jackman
C. T. Jackson
R. H. Jordan
C. M. Long
Roy Lumpkin
F. G. Campbell, *Vice Chairman,*
T. P. Lynch
R. B. Midkiff
L. E. Peterson
Arthur Price
W. W. Rohrbough
E. F. Salisbury
T. D. Saunders
W. D. Simpson
J. G. Sutherland
W. H. Vance
A. W. White
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including recommended revisions of the Manual ..... page 238

2. Extent of adherence to specifications.

   Progress report, presented as information ..... page 238

3. Substitutes for wood ties.

   No report.

4. Tie renewals and costs per mile of maintained track.

   Progress report, presented as information ..... page 239

5. Cause and control of splitting in railroad ties.

   No report.

6. Ways and means for retarding the destruction of ties by mechanical wear.

   No report.

7. Causes leading to the removal of ties.

   No report.

8. Dimensions of ties.

   Progress report, presented as information ..... page 239

The Committee on Ties,
C. D. Turley, *Chairman.*

AREA Bulletin 470, December 1947.

Report on Assignment 1

Revision of Manual

H. R. Duncan (chairman, subcommittee), R. S. Belcher, W. J. Burton, R. E. Butler, F. G. Campbell, B. S. Converse, B. D. Howe, W. D. Simpson, C. D. Turley.

Your committee has made a further study of its chapter in the Manual and recommends the following:

Pages 3–9 and 10

Specifications for Machining Crossties
1936

Submitted for reapproval without change.

Page 3–20

Traffic Unit for Use in Comparing Cross Tie Life
1930

Submitted for reapproval without change.

Best Practice for Tie Renewals
1930

Submitted for reapproval without change.

Pages 3–23 and 24

Specifications for Dating Nails
1930

Submitted for reapproval without change.

Report on Assignment 2

Extent of Adherence to Specifications

W. D. Simpson (chairman, subcommittee), M. L. Bardill, W. H. Brameld, P. D. Brentlinger, H. F. Brown, G. B. Campbell, R. W. Cook, T. H. Friedlin, L. E. Gingerich, B. D. Howe, C. M. Long, Roy Lumpkin, R. B. Midkiff, Arthur Price, W. W. Rohrbough, E. F. Salisbury, T. D. Saunders, A. W. White.

The committee has been able again this year to make the usual field inspections and observe the extent of adherence to specifications. Eight treating plants were visited and approximately 2,600,000 ties were observed. These ties representing the seasoning stocks of nine railroads, were largely pine, gum and oak and were produced in Mississippi, Louisiana, Missouri, Arkansas and East Texas.

Lift trucks for handling green ties from cars to seasoning yards, and for handling seasoned ties from seasoning yards to boring and adzing mills were in use at four of the eight plants visited. The committee was impressed with the many advantages of this method of handling ties and with the excellent job of stacking being obtained. If the green ties are segregated and stacked according to size, there is no occasion for further separation when treating and as a result the seasoning yard will always be in order and there will be no layout ties to be damaged by having contact with the ground.

Although not all seasoning yards have reverted fully to prewar practices and stocks of ties, the committee was greatly encouraged by improvements already made and by the apparent general effort of all the roads to correct conditions as rapidly as possible.

Report on Assignment 4

Tie Renewals and Costs Per Mile of Maintained Track

C. D. Turley (chairman, subcommittee), W. C. Bolin, W. H. Brameld, W. J. Burton, C. T. Jackson, Roy Lumpkin, T. P. Lynch, J. G. Sutherland, A. W. White.

Information reported annually to the Interstate Commerce Commission by Class I steam railways in the United States and to this Association by large railroads in Canada, regarding the number and cost of the cross ties laid in replacement is supplied for 1946 in Tables A and B. These tabulations were published in Bulletin No. 467, June–July 1947, in order to make the information available as promptly as possible.

Decreased tie replacements in 1946 reflect unfavorable factors that prevailed during the year, including a shortage of track labor in some localities due partly to the loss of a large force of Mexican workers early in the year, and also to greatly increased labor costs without corresponding increases in freight and passenger rates.

The rise in the cost of ties which began in 1941 and extended through 1942–1945, incl., has continued through 1946.

Comparison of the tie service records of individual railroads cannot be accurately made unless all information involved is available and taken into consideration, including tie renewal cycles, and traffic and maintenance conditions.

Report on Assignment 8

Dimensions of Ties

W. J. Burton (chairman, subcommittee), R. S. Belcher, P. D. Brentlinger, H. F. Brown, H. R. Duncan, B. D. Howe, C. E. Jackman, C. M. Long, W. D. Simpson, A. W. White.

This report is submitted as information.

Dimensions Other Than Length

No changes in the recommended cross-section sizes are proposed at this time.

Review of Reports Regarding Length of Cross Ties

At the 1939 convention this committee presented an analysis of the functions of the cross tie and showed that ties were too short to be most efficient in spreading the concentrated load from the rails and tie plates over the ballast and subgrade. It was shown that because ties are too short, the practice of not tamping them at the center of the track is necessary as an expedient to avoid "center-bound" track. It was shown that an increase of tie length permitted a decrease in the untamped (and thus wasted) part of the tie support at the center of the track. It was demonstrated that with present rail sections a tie about 10 ft. long would be needed to permit the tamping of the entire tie length without noticeable tendency towards center-bound track (Proceedings, Vol. 40, 1939, page 686).

Because 10-ft. ties were considered as being too costly to be justified, the committee, in 1941, recommended:

(a) The adoption of 9-ft. ties and the discontinuance of the purchase of 8-ft. ties as rapidly as practicable and economical:

(b) The use of 9-ft. ties at least for lines of heavy traffic:

(c) The adoption of the 9-ft. length wherever a change is made from the 8-ft. length (Proceedings, Vol. 42, 1941, page 487).

These recommendations were adopted for the Manual (Proceedings, Vol 43, 1942, page 698).

Situation Resulting from World War II

About the time the committee recommended the 9-ft. ties, two large railroads, (the Santa Fe and the Atlantic Coast Line) adopted this length as standard. It seems likely that similar action would have been taken by other railroads had it not been for the abnormal conditions resulting from Pearl Harbor. The experience of these two roads with the 9-ft. ties amply confirms the wisdom of the step. Reports are included from these roads.

Discussion For and Against the Change to Longer Ties

In the reports cited it has been shown that tie lengths in the past had resulted from practices relating to lengths of commercial lumber without regard for the fact that the best tie length is a function of the gage of track. It has been shown that the longer ties provide additional support considerably out of proportion to the increased cost. The longer ties reduce the amount of wasted ballast at the center of the track, and for a given yardage of ballast will produce greater track support.

The increased cost of longer ties has been shown to be less than might at first be assumed. Observation by this committee, confirmed by U. S. Forest Service representatives, and by commercial producers, indicates that comparatively few trees cut for ties will not make as many 9-ft. ties as 8-ft. 6-in. or 8-ft. ties. Stumps 2 to 3 ft. high, left as waste, are not uncommon. The cost of manufacture, whether by hand or saw mill, is almost wholly independent of length. Some additional cost for treatment is to be expected, due to fewer trams per cylinder charge. Where commercial freight is paid, the increase will be proportional to the increase in length. Costs for insertion are largely independent of length.

That the committee's statements about increased cost of longer ties being minor are reasonable is supported by experience during the late war. The OPA fixed a price differential of 10 cents between 8-ft. and 8-ft. 6-in. ties. The result was that the 8-ft. ties could not be obtained because the producers elected to supply the longer tie at the 10 cent higher price. In other words, it did not cost them 10 cents more to produce the longer tie.

It should be pointed out that in any comparisons between ties, the total cost in track, including insertion, transportation, treatment, etc., should be used, rather than the mere first cost of the tie itself. Present day total costs, which usually are over four dollars per tie in track, justify better ties than when this cost was only half as much.

The adoption of longer ties necessarily disturbs the appearance of the track, particularly where the practice has been to maintain a "line side" and a "gage side" to the track. A 9-ft. tie inserted in 8-ft. tie track (and centered, as it should be) must stand out 6 in. beyond the tie line, and this ragged appearance will continue until renewals have removed all of the shorter ties. The appearance of track is, of course, important, but perhaps less so than formerly, because present day passenger trains invited much less track inspection from the rear car; the passenger is entertained otherwise than in observing the track.

In view of the above, and of the experience with 9-ft. ties as reported by the two railroads which have adopted them as standard, this committee reaffirms the recommendations as to length made in 1941 and now to be found in the Manual.

Table A

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I STEAM RAILWAYS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1946

Table A

Sheet 1 of 2 sheets

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I STEAM RAILWAYS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1946

Road	Cross ties laid in replacement								Miles of main-tained tracks (item 24)	Estimated total cross ties in all maintained tracks (item 25)	Average number of cross ties per mile of main-tained track	Number of equated gross ton-miles (thousands)	Number of equated gross ton-miles per mile of main-tained track (thous.)	New wooden cross tie replacement averages			
	New wooden ties untreated (U)		New wooden ties treated (T)		Total all new wooden ties laid		Ties other than wood(S) & second-hand(*) reapplied ties	Total ties applied						Per cent renewals to main-ties in track	Number laid per mile of main-tained track	Renewal cost per mile of main-tained track	Renewal cost per 1000 equated gross ton-miles
	Number	Aver-age cost	Number	Aver-age cost	Number	Aver-age cost											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NEW ENGLAND REGION:																	(cents)
Bangor & Aroostook	77 750	$1.41	88 132	$2.97	165 912	$2.24	-	165 912	820.80	2 376 118	2 874	1 898 445	2 296	7.0	201	$449	19.54
Boston & Maine	-	-	137 274	2.62	137 274	2.62	-	137 274	2 893.00	8 534 400	2 950	17 377 216	6 007	1.6	47	124	2.07
Canadian Net.Lines in New Eng.	710	0.93	20 164	1.82	20 874	1.79	-	20 874	237.61	752 236	3 166	611 228	2 572	2.8	88	157	6.12
Canadian Pacific (lines in Me.)	600	1.46	16 712	2.17	17 312	2.15	-	17 312	215.85	671 603	3 111	2 072 918	9 604	2.6	80	172	1.79
Canadian Pacific (lines in Vt.)	-	-	11 670	1.98	11 670	1.98	-	11 670	125.35	377 467	3 011	694 071	5 537	3.1	93	184	3.33
Central Vermont	-	-	20 440	2.23	20 440	2.23	* 1 286	21 726	495.04	1 463 000	2 955	2 474 522	4 999	1.4	41	92	1.84
Maine Central	36 777	1.38	65 117	3.04	101 894	2.44	* 7 587	109 481	1 213.98	3 681 400	3 033	4 555 241	3 753	2.8	84	205	5.47
New York Connecting	-	-	1 000	3.20	1 000	3.20	-	1 000	25.90	81 641	3 152	402 877	15 555	1.2	39	123	0.79
New York,New Haven & Hartford	-	-	380 647	2.61	380 647	2.61	-	380 647	3 818.20	11 972 160	3 136	27 329 104	7 158	3.2	100	261	3.64
Rutland	-	-	24 617	2.37	24 617	2.37	* 257	24 874	486.19	1 511 500	3 109	1 672 558	3 440	1.6	51	120	3.48
Total	115 837	1.40	765 803	2.63	881 640	2.47	9 130	890 770	10 337.82	31 421 525	3 039	59 088 180	5 716	2.8	85	211	3.69
GREAT LAKES REGION:																	
Ann Arbor	-	-	42 076	2.39	42 076	2.39	-	42 076	402.69	1 221 344	3 033	1 720 965	4 274	3.4	104	249	5.83
Canbria & Indiana	-	-	6 199	2.75	6 199	2.75	-	6 199	56.43	162 327	2 877	133 414	2 364	3.8	110	303	12.80
Delaware & Hudson	3	1.33	182 532	2.89	181 535	2.89	(S) 126	181 661	1 358.21	4 217 658	3 105	14 542 524	10 707	4.3	134	386	3.60
Delaware,Lack.& Western	-	-	169 652	2.62	169 652	2.62	* 8 657	178 309	2 205.92	6 397 628	2 900	17 508 658	7 937	2.7	77	202	2.54
Detroit & Mackinac	18 039	1.18	6 270	2.06	24 309	1.41	-	24 309	276.43	828 197	2 997	287 716	1 041	2.9	89	124	11.88
Detroit & Toledo Shore Line	-	-	7 843	2.63	7 843	2.63	* 1 008	8 851	148.81	449 069	3 018	710 853	4 777	1.7	53	138	2.90
Erie	277	0.91	289 743	2.60	290 020	2.59	-	290 020	4 713.85	13 957 227	2 961	41 818 189	8 871	2.1	62	160	1.80
Grand Trunk Western	-	-	259 014	2.60	259 014	2.60	-	259 014	1 849.03	5 857 637	3 168	10 022 087	5 420	4.4	140	365	6.71
Lehigh & Hudson River	-	-	11 030	3.07	11 030	3.07	* 1 279	12 309	111.79	300 500	2 688	941 800	8 425	3.7	99	303	1.60
Lehigh & New England	-	-	15 534	2.84	15 534	2.84	-	15 534	257.87	780 173	3 025	1 105 559	4 287	2.0	60	171	1.99
Lehigh Valley	-	-	233 309	2.81	233 309	2.81	-	233 309	2 615.18	7 786 409	2 977	16 785 395	6 418	3.0	89	251	3.91
Monongahela	-	-	21 627	2.61	21 627	2.61	-	21 627	238.03	694 913	2 919	1 234 216	5 185	3.1	91	237	4.57
Montour	5 662	2.20	-	-	5 662	2.20	-	5 662	72.39	208 494	2 880	325 199	4 492	2.7	78	172	3.83
New York Central	768	1.95	2 097 280	2.62	2 098 048	2.62	* 2 496	2 100 544	20 967.73	64 868 558	3 094	187 687 490	8 951	3.2	100	262	2.93
New York,Chicago & St.Louis	-	-	383 650	2.71	383 650	2.71	-	383 650	2 544.27	8 014 328	3 150	24 717 231	9 715	4.8	151	409	4.21
New York,Ontario & Western	-	-	294	2.65	294	2.65	* 4 183	4 477	716.98	2 036 286	2 840	2 231 903	3 113	[illegible]	[illegible]	1	0.03
New York,Susq.& Western	-	-	7 113	2.40	7 113	2.40	-	7 113	214.76	624 900	2 910	338 880	1 778	1.1	33	79	4.47
Pere Marquette	-	-	213 571	2.32	213 571	2.32	-	213 571	2 576.79	7 681 967	2 981	13 837 982	5 370	2.8	83	193	3.59
Pittsburgh & Lake Erie	-	-	84 726	2.31	84 726	2.31	-	84 726	834.68	2 520 213	3 019	4 934 876	5 912	3.4	102	234	3.96
Pittsburgh & Shawmut	106	1.00	20 063	2.01	20 169	3.00	* 591	20 760	115.46	327 218	2 834	329 469	2 854	6.2	175	324	18.36
Pittsburgh & West Virginia	-	-	20 058	3.12	20 058	3.12	-	20 058	182.14	554 258	3 043	1 046 150	5 744	3.6	110	343	5.97
Pittsburg,Shawmut & Northern	666	1.32	809	2.42	1 475	1.92	* 1 654	3 129	218.84	642 800	2 937	133 692	611	0.2	7	13	2.12
Ashtabula	-	-	324 026	2.46	324 026	2.46	-	324 026	3 159.90	9 845 181	3 116	25 994 605	8 226	3.3	103	252	3.07
Total	25 521	1.43	4 395 419	2.62	4 420 940	2.61	19 994	4 440 934	45 838.18	139 777 185	3 049	368 431 853	8 038	3.2	96	252	3.13
CENTRAL EASTERN REGION:																	
Akron,Canton & Youngstown	48 898	2.11	8 852	1.99	57 750	2.09	-	57 750	214.86	618 797	2 880	866 784	4 034	9.3	269	563	13.95
Baltimore & Ohio	-	-	1 273 716	2.25	1 273 716	2.25	(S) 4	1 273 720	10 348.74	29 509 919	2 852	95 255 298	9 205	4.3	123	277	3.01
Bessemer & Lake Erie	-	-	14 562	3.26	14 562	3.26	-	14 562	487.31	1 515 284	3 109	3 915 753	8 035	1.0	30	97	1.21
Central R.R.of New Jersey	-	-	122 711	2.46	122 711	2.46	-	122 711	932.72	2 621 910	2 811	7 856 533	8 423	4.7	132	323	3.84
Central R.R.of Pennsylvania	-	-	12 242	2.59	12 242	2.59	-	12 242	473.07	1 329 936	2 811	1 463 957	3 095	2.4	68	176	5.70
Chicago & Eastern Illinois	-	-	182 553	2.29	182 553	2.29	-	182 553	1 290.05	4 000 316	3 101	7 757 632	6 013	4.6	142	324	5.39
Chicago & Illinois Midland	-	-	5 752	2.79	5 752	2.79	-	5 752	169.96	496 371	2 921	1 348 195	7 932	1.2	34	94	1.19
Chicago,Indpls.& Louisville	-	-	52 840	2.16	52 840	2.16	* 675	53 515	731.86	2 268 841	3 100	2 969 823	4 058	2.3	72	156	3.84
Detroit,Toledo & Ironton	1 896	0.89	34 518	2.17	36 414	2.10	-	36 414	602.77	1 735 977	2 880	2 047 274	3 396	2.1	60	127	3.73
Elgin,Joliet & Eastern	-	-	84 430	2.20	84 430	2.20	* 7 824	92 254	854.46	2 636 678	3 086	3 673 212	4 300	3.2	99	218	5.05
Illinois Terminal Co.	825	1.52	50 239	3.97	51 064	3.96	-	51 064	633.72	1 901 160	3 000	1 233 442	1 946	2.7	81	158	8.12
Long Island	-	-	69 003	3.11	69 003	3.11	-	69 003	795.33	2 271 314	2 856	4 753 394	5 977	3.0	87	270	4.51
Missouri-Illinois	50	0.76	41 096	2.06	41 146	2.05	-	41 146	214.94	673 610	3 134	439 473	2 045	6.1	191	393	19.24
Pennsylvania	-	-	1 968 185	2.49	1 968 185	2.49	(t)1 217	1 969 402	21 384.51	61 032 324	2 854	240 613 805	11 252	3.2	92	229	2.04
Penna.-Reading Seashore Lines	-	-	58 500	2.99	58 500	2.99	-	58 500	634.90	1 725 247	2 717	1 747 555	3 099	3.4	92	259	3.76
Reading	-	-	320 163	2.60	320 163	2.60	-	320 163	2 861.64	7 959 733	2 781	22 097 893	7 669	4.0	111	289	3.76
State Island Rapid Transit	-	-	10 012	2.50	10 012	2.50	-	10 012	92.47	236 720	2 560	269 364	2 913	4.2	108	270	9.29
Western Maryland	894	1.91	81 723	2.54	82 617	2.53	-	82 617	1 145.26	3 322 224	2 901	8 845 430	7 724	2.5	72	183	2.37
Wheeling & Lake Erie	-	-	77 388	2.38	77 388	2.38	* 3 795	81 183	830.31	2 511 246	3 003	4 042 700	5 551	3.1	93	220	3.97
Total	52 563	2.05	4 488 485	2.42	4 541 048	2.41	13 515	4 554 563	44 724.88	128 397 607	2 871	412 023 517	9 212	3.5	102	245	2.66
POCAHONTAS REGION:																	
Chesapeake & Ohio	-	-	500 521	2.49	500 521	2.49	-	500 521	5 132.50	15 765 784	3 072	67 935 812	13 236	3.2	98	242	1.83
Norfolk & Western	-	-	365 643	2.24	365 643	2.24	* 4 000	369 643	4 276.41	13 256 871	3 100	46 931 424	10 974	2.6	86	191	1.74
Richmond,Fred.& Potomac	-	-	39 412	2.38	39 412	2.38	* 2 136	41 548	401.79	1 202 550	2 993	7 343 819	18 276	3.4	98	231	1.27
Virginian	-	-	74 221	1.88	74 221	1.88	-	74 221	918.65	2 824 240	3 074	8 500 423	9 253	2.6	81	152	1.64
Total	-	-	979 797	2.34	979 797	2.34	6 136	985 933	10 729.35	33 009 395	3 077	130 711 478	12 183	3.0	91	214	1.76
SOUTHERN REGION:																	
Alabama Great Southern	-	-	125 065	2.62	125 065	2.62	-	125 065	551.61	1 665 154	3 019	4 707 385	8 534	7.5	227	594	6.96
Atlanta & West Point	9 282	1.91	20 859	2.57	30 141	2.37	-	30 141	141.11	436 027	3 090	966 143	6 847	6.9	214	501	7.39
Atlantic Coast Line(inc.ASSC)	184 271	1.08	1 950 430	2.51	2 134 701	2.44	-	2 134 701	7 424.78	22 274 340	3 000	42 235 723	5 688	9.6	288	707	12.23
Central of Georgia	400	1.40	347 851	1.94	348 251	1.94	-	348 251	2 265.92	6 696 776	2 955	10 575 440	4 667	5.2	154	298	6.39
Charleston & western Carolina	5 420	2.14	78 716	2.71	84 136	2.73	-	84 136	426.77	1 231 027	2 883	1 131 851	2 652	6.8	197	533	20.32
Clin.,New Orleans & Tex.Pac.	100	1.78	71 910	2.53	72 010	2.54	-	72 010	770.64	2 451 316	2 921	9 523 714	12 747	3.2	93	241	1.89
Clinchfield	25 723	1.49	43 073	2.27	68 796	1.97	-	68 796	338.39	1 211 102	3 040	4 119 801	10 341	5.7	173	340	3.29
Columbus & Greenville	31	0.58	31 625	2.24	31 656	2.24	-	31 656	205.80	651 974	3 168	339 864	1 651	4.9	154	344	20.83
Florida East Coast	28 471	1.67	195 704	2.66	224 235	2.53	-	224 235	1 262.06	3 628 499	2 875	7 733 874	6 128	6.2	176	450	7.14
Georgia	23 547	1.56	32 344	2.51	56 191	2.23	-	56 191	426.25	1 342 315	3 063	2 266 942	5 177	4.2	125	287	5.53
Georgia & Florida	116 485	1.56	-	-	116 485	1.56	-	116 485	453.94	1 241 538	2 720	694 473	1 510	9.4	253	376	26.23
Georgia,Southern & Florida	75 890	1.54	14 033	2.70	90 523	1.71	-	90 523	464.54	1 462 777	3 147	1 918 465	4 127	6.2	195	334	8.09
Gulf,Mobile & Ohio	6 781	1.56	431 966	2.21	438 747	2.20	* 1 168	439 915	2 044.37	6 476 561	3 168	10 775 600	5 271	6.8	215	473	8.98
Illinois Cent.(inc.GASI & YAMV)	74	1.58	2 044 885	2.27	2 044 959	2.27	(S) 349	2 045 308	9 84.22	30 013 112	3 050	65 564 360	6 663	6.8	206	472	7.09
Louisville & Nashville	534	1.02	871 380	2.21	872 514	2.21	-	872 514	6 721.44	19 241 031	2 863	52 659 561	7 835	4.5	130	297	1.66
Mississippi Central	143	1.07	16 644	2.17	16 787	2.16	-	16 787	171.53	592 146	3 453	247 173	1 415	3.1	93	211	14.68
Nashville,Chatt.& St.Louis	-	-	178 752	2.33	178 752	2.33	-	178 752	1 447.79	3 984 868	2 752	9 452 675	6 528	4.5	123	288	4.41
New Orleans & Northeastern	-	-	69 076	2.73	69 076	2.73	-	69 076	289.39	827 920	2 861	2 714 237	9 379	6.3	239	651	6.94
Norfolk Southern	117 686	1.53	99 743	2.57	217 429	2.01	-	217 429	852.60	2 424 507	2 844	1 931 526	2 265	8.8	255	511	22.57
Samboard Air Line	1o 135	1.62	912 467	2.33	928 605	2.31	-	928 605	5 319.00	1o 090 701	2 065	3o 669 548	6 894	5.8	175	454	5.96
Southern Ry.	11 099	1.56	1 156 238	2.51	1 167 337	2.50	-	1 167 337	5 60.49	26 602 360	3 031	62 413 693	7 290	4.4	136	380	5.21
Tennessee Central	1o 593	1.41	30 204	2.34	40 843	2.01	-	40 843	341.94	1 035 394	3 028	960 640	2 809	4.5	137	275	9.80
Western Ry.of Alabama	15 187	1.89	18 691	2.58	33 858	2.27	-	33 858	184.74	562 280	3 044	1 072 030	5 803	6.0	193	416	7.17
Total	454 121	1.81	8 742 981	2.41	9 397 102	2.36	1 517	9 398 619	30 624.12	151 365 255	3 002	331 179 020	6 542	6.2	186	437	6.69

Table A

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I STEAM RAILWAYS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1946

	Gross ties laid in replacement					Miles of	Estimated total	Average number of cross	Number of	Number of equated gross	New wooden cross tie replacement averages			
	New	New	Total all	Ties								Number	Renewal	Renewal

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I STEAM RAILWAYS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1946

Road	Gross ties laid in replacement								Miles of main-tained tracks (item 24)	Estimated total cross ties in all maintained tracks (item 25)	Average number of cross ties per mile of main-tained track	Number of equated gross ton-miles a (thousands)	Number of equated gross ton-miles per mile of main-tained track (thous.)	New wooden cross tie replacement averages			
	New wooden ties untreated (U)		New wooden ties treated (T)		Total all new wooden ties laid		Ties other than wood (S) & second-hand(e) reapplied	Total ties applied						Per cent renewal to all ties in track	Number laid per mile of main-tained track	Renewal cost per mile of main-tained track	Renewal cost per 1000 equated gross ton-miles
	Number	Aver-age cost	Number	Aver-age cost	Number	Aver-age cost											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NORTHWESTERN REGION:																	(cents)
Chicago & North Western	27 476	$1.19	1 326 658	$2.00	1 354 134	$1.99	-	1 354 134	11 199.00	33 195 827	2 964	49 218 853	4 395	4.1	121	$240	5.47
Chicago Great Western	107 774	1.97	182 880	2.63	290 654	2.39	-	290 654	1 876.22	5 563 363	2 965	10 519 294	5 607	5.2	155	370	6.60
Chicago, Milwaukee, St.Paul & Pac.	107 887	0.45	1 373 736	2.07	1 481 623	1.95	-	1 481 623	13 551.63	41 939 696	3 095	66 088 994	4 877	3.5	109	213	4.37
Chicago, St.Paul, Minpls. & Omaha	2 974	1.08	237 422	2.27	240 396	2.26	-	240 396	2 149.47	6 373 105	2 965	8 299 161	3 861	3.8	112	253	6.55
Duluth, Missabe & Iron Range	7 435	1.24	62 201	2.16	69 636	2.06	-	69 636	1 080.07	3 217 529	2 979	6 131 270	5 677	2.2	64	133	2.34
Duluth, South Shore & Atlantic	13 786	1.24	60 066	2.08	73 852	1.92	-	73 852	518.74	1 556 220	3 000	1 221 534	2 355	4.7	142	273	11.60
Duluth, Winnipeg & Pacific	17 497	1.40	43 499	1.91	60 996	1.77	-	60 996	207.00	607 707	2 936	807 313	3 900	10.0	295	521	13.35
Great Northern	14 121	0.87	962 525	1.87	976 646	1.85	• 34 356	1 011 002	10 223.48	31 477 737	3 079	54 610 171	5 342	3.1	96	177	3.32
Green Bay & Western	19 685	1.41	20 294	3.06	39 979	2.25	-	39 979	282.47	813 514	2 880	751 335	2 660	4.9	142	318	11.95
Lake Superior & Ishpeming	16 755	1.42	19 039	2.62	35 794	2.06	-	35 794	237.55	712 650	3 000	162 632	685	5.0	151	310	45.35
Minneapolis & St.Louis	39 784	1.27	133 932	2.06	173 716	1.88	-	173 716	1 564.72	4 724 970	3 020	3 849 758	2 460	3.7	111	209	8.48
Minneapolis, St.Paul & SS Marie	39 442	1.06	457 960	2.02	497 402	1.94	-	497 402	4 801.13	14 182 878	2 954	16 046 618	3 342	3.5	104	201	6.02
Northern Pacific	6 776	1.12	555 319	1.81	562 095	1.80	-	562 095	9 268.93	26 906 844	2 903	47 319 940	5 105	2.1	61	109	2.14
Spokane International	52 066	1.22	-	-	52 066	1.22	-	52 066	177.20	514 765	2 905	311 866	1 760	10.1	294	358	20.35
Spokane, Portland & Seattle	4 870	0.24	128 620	2.21	133 490	2.14	-	133 490	1 124.51	3 485 981	3 100	5 991 227	5 328	3.8	119	253	4.76
Wisconsin Central							Included in report of Minneapolis, St.Paul & SS Marie										
Total	478 328	1.21	5 564 151	2.02	6 042 479	1.96	34 356	6 076 835	58 262.12	175 272 786	3 008	271 329 966	4 657	3.4	104	203	4.36
CENTRAL WESTERN REGION:																	
Alton	84 198	1.85	283 801	2.82	367 999	2.60	a 2 099	370 098	1 487.91	4 487 833	3 016	8 624 620	5 796	8.2	247	643	11.10
Atchison, Topeka & Santa Fe	65	2.05	1 540 066	1.83	1 540 131	1.83	-	1 540 131	19 223.93	58 383 075	3 037	154 843 636	8 055	2.6	80	147	1.82
Chicago, Burlington & Quincy	-	-	1 501 502	2.05	1 501 502	2.05	•134 568	1 636 070	11 896.80	36 737 319	3 088	65 858 091	5 536	4.1	126	258	4.67
Chicago, Rock Island & Pacific	-	-	1 036 235	2.17	1 036 235	2.17	-	1 036 235	9 511.12	28 516 625	2 998	55 703 681	5 857	3.6	109	236	4.03
Colorado & Southern	-	-	85 786	2.16	85 786	2.16	a 3 819	89 605	831.93	2 495 790	3 000	3 719 981	4 472	3.4	103	222	4.97
Colorado & Wyoming	-	-	4 294	2.95	4 294	2.95	-	4 294	108.21	312 103	2 884	23 488	217	1.4	40	117	53.87
Denver & Rio Grande Western	-	-	110 771	2.19	110 771	2.19	• 59 236	170 007	3 136.34	9 770 300	3 115	17 842 464	5 689	1.1	35	77	1.36
Denver & Salt Lake	-	-	54 895	2.27	54 895	2.27	-	54 895	324.92	1 039 840	3 200	899 410	2 768	5.3	169	384	13.87
Fort Worth & Denver City	-	-	158 075	2.15	158 075	2.15	a 3 284	161 359	1 032.07	3 072 292	2 977	4 033 176	3 908	5.1	153	329	8.42
Northwestern Pacific	46 417	1.79	13 700	1.64	60 117	1.76	-	60 117	421.94	1 221 611	2 895	1 026 071	2 432	4.9	142	251	10.30
Southern Pacific Co.- Pac.Lines	78 427	1.45	832 002	1.87	910 429	1.84	a 3 024	913 453	11 868.73	36 838 321	3 104	130 560 428	11 000	2.5	77	141	1.28
Toledo, Peoria & Western & Union Pacific	5 436	1.30	909 783	1.76	915 219	1.76	-	915 219	13 151.29	37 161 770	2 826	130 427 830	9 917	2.5	70	123	1.24
Utah	208	1.32	5 852	2.56	6 060	2.51	a 516	6 576	71.13	202 261	2 844	422 416	5 939	3.0	85	214	3.61
Western Pacific	120 917	1.71	66 845	2.56	187 762	2.01	a 140	187 902	1 528.58	4 575 948	2 994	14 113 822	9 233	4.1	123	247	2.67
Total	335 668	1.69	6 603 607	2.00	6 939 275	1.99	206 686	7 145 961	74 594.90	224 815 088	3 014	588 099 114	7 884	3.1	93	185	2.34
SOUTHWESTERN REGION:																	
Beaumont, Sour Lake & Western	-	-	27 077	2.17	27 077	2.17	-	27 077	148.86	443 200	2 977	1 844 792	12 393	6.1	182	395	3.19
Burlington-Rock Island	-	-	24 464	2.13	24 464	2.13	-	24 464	178.24	557 891	3 130	932 704	5 233	4.4	137	292	5.58
International-Great Northern	-	-	201 372	2.22	201 372	2.22	-	201 372	1 419.52	4 254 000	2 997	8 594 248	6 054	4.7	142	315	5.19
Kansas City Southern	15	1.53	69 665	2.02	69 680	2.02	• 97	69 777	1 245.87	3 945 935	3 167	9 367 014	7 518	1.8	56	113	1.51
Kansas, Oklahoma & Gulf	-	-	19 194	2.12	19 194	2.12	-	19 194	350.07	1 036 207	2 960	1 230 162	3 514	1.9	55	116	3.31
Louisiana & Arkansas	-	-	21 838	2.02	21 838	2.02	-	21 838	867.45	2 823 337	3 255	3 394 175	3 913	0.8	25	51	1.30
Midland Valley	-	-	21 779	2.06	21 779	2.06	-	21 779	356.86	1 056 245	2 960	405 265	1 136	2.1	61	126	11.09
Missouri & Arkansas	26 049	1.41	9 361	1.65	35 410	1.47	• 153	35 563	358.50	1 116 201	3 114	358 207	999	3.2	99	145	14.53
Missouri-Kansas-Texas Lines	-	-	357 871	2.14	357 871	2.14	-	357 871	3 905.83	12 291 200	3 147	19 388 160	4 964	2.9	92	196	3.95
Missouri Pacific	3 909	1.35	977 588	2.06	981 497	2.05	-	981 497	8 905.61	27 477 621	3 085	61 136 138	6 865	3.6	110	226	3.30
New Orleans, Texas & Mexico	-	-	30 832	2.18	30 832	2.18	-	30 832	224.41	686 500	3 059	1 428 958	6 368	4.5	137	300	4.71
Oklahoma City-Ada-Atoka	881	1.17	33 430	2.13	34 311	2.10	-	34 311	138.25	398 160	2 880	130 740	946	8.6	248	522	55.21
St.Louis, Brownsville & Mexico	-	-	119 909	2.12	119 909	2.12	-	119 909	762.26	2 305 700	3 025	4 543 449	5 960	5.2	157	334	5.60
St.Louis-San Francisco	144 955	1.52	542 789	2.02	687 744	1.92	-	687 744	6 220.99	19 584 833	3 148	31 694 910	5 095	3.5	111	212	4.16
St.Louis, San Francisco & Texas	2 538	1.52	16 260	1.91	18 798	1.85	-	18 798	154.29	482 106	3 125	782 265	5 070	3.9	122	226	4.46
St.Louis Southwestern	-	-	294 955	2.14	294 955	2.14	a 855	295 810	1 875.72	5 806 807	3 096	13 685 755	7 296	5.1	158	338	4.64
San Antonio, Uvalde & Gulf	-	-	53 404	2.20	53 404	2.20	-	53 404	367.52	1 036 700	2 821	689 670	1 877	5.2	145	319	17.01
Texas & New Orleans	-	-	635 248	1.93	635 248	1.93	-	635 248	5 541.82	15 315 669	2 764	32 170 433	5 805	4.1	115	221	3.81
Texas & Pacific	-	-	414 059	1.80	414 059	1.80	-	414 059	2 291.56	6 698 700	2 923	17 858 044	7 793	6.2	181	325	4.16
Texas Mexican	380	1.26	15 841	2.17	16 221	2.15	-	16 221	205.31	650 422	3 168	215 817	1 051	2.5	79	170	16.14
Total	178 727	1.50	3 888 936	2.03	4 067 663	2.01	1 105	4 068 768	35 518.94	107 967 434	3 040	209 850 906	5 908	3.8	115	230	3.89
Grand Total, United States	1 840 765	1.51	35 429 179	2.26	37 269 944	2.22	292 439	37 562 383	330 630.31	992 626 275	3 002	2 370 714 034	7 170	3.8	113	251	3.50
CANADIAN ROADS:																	
Canadian National	1 250 142	1.11	2 890 473	1.81	4 140 615	1.60	-	4 140 615	26 899.00	78 813 515	2 930	g	g	5.3	154	246	g
Canadian Pacific	1 021 142	1.12	2 115 713	1.96	3 137 055	1.69	-	3 137 055	21 102.00	60 636 058	2 873	94 816 163	4 493	5.2	149	251	5.58
Ontario Northland	127 [illegible]	1.16	11 876	1.95	139 633	1.23	-	139 633	679.70	1 970 350	2 899	2 248 503	3 308	7.1	205	252	7.62

g Gross ton-miles of cars and contents, plus two times gross ton-miles of locomotives and tenders in freight service, plus three times gross ton-miles of locomotives & tenders in passenger service.
h Less than one-tenth of one per cent.
i Less than one tie per mile of track.
d No report filed.
z Not reported.
t Tunnel ties

Note: "Average Cost" as shown in Columns 3, 5 and 7, represents storekeepers average cost of ties charged out and used. They are not the actual costs or the prices paid for the ties purchased during the period.

Compiled by
Association of American Railroads, Bureau of Railway Economics, Washington, D.C.
from Annual Reports of Class I Railways to the Interstate Commerce Commission.
June 23, 1947.

Table B

Table B

NUMBER AND AGGREGATE COST OF NEW WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOODEN CROSS TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of the five years 1942 to 1946, inclusive

Note: All figures are exclusive of bridge and switch ties

Road	Number of new wooden cross tie renewals per mile of maintained track						Aggregate cost of new wooden cross tie renewals per mile of maintained track						Per cent new wooden cross tie renewals to all ties in tracks					
	1942	1943	1944	1945	1946	5 year average	1942	1943	1944	1945	1946	5 year average	1942	1943	1944	1945	1946	5 year average
NEW ENGLAND REGION:																		
Bangor & Aroostook	158	114	109	110	201	138	$99	$84	$195	$231	$449	$212	5.5	4.0	3.8	3.8	7.0	4.8
Boston & Maine	106	66	72	42	47	67	186	131	157	101	124	140	3.6	2.2	2.4	1.4	1.6	2.2
Canadian Net.Lines in New England	127	80	112	126	88	107	154	104	174	211	157	160	4.1	2.6	3.6	4.0	2.8	3.4
Canadian Pacific (lines in Me.)	60	71	63	82	80	71	98	91	108	154	172	125	2.0	2.4	2.0	2.6	2.6	2.3
Canadian Pacific (lines in Vt.)	99	74	116	86	93	94	141	96	230	168	184	164	3.3	2.5	3.9	2.9	3.1	3.1
Central Vermont	53	29	23	21	41	33	77	44	40	42	92	59	1.8	1.0	0.8	0.7	1.4	1.1
Maine Central	142	119	126	124	84	119	215	208	246	299	205	235	4.7	3.9	4.1	4.1	2.8	3.9
New York Connecting	223	154	127	132	39	135	559	430	365	400	123	375	7.1	4.9	4.0	4.2	1.2	4.3
New York,New Haven & Hartford	66	67	87	77	100	79	118	146	196	190	261	182	2.1	2.1	2.8	2.5	3.2	2.5
Rutland	46	45	45	39	51	45	67	63	81	83	120	83	1.5	1.5	1.4	1.2	1.6	1.4
Total	94	74	84	72	85	82	145	133	177	169	211	167	3.1	2.4	2.8	2.4	2.8	2.7
GREAT LAKES REGION:																		
Ann Arbor	93	90	94	97	104	96	145	154	198	213	249	192	3.1	3.0	3.1	3.2	3.4	3.2
Cambrie & Indiana	235	326	211	177	110	212	553	842	563	416	303	535	8.6	11.9	7.4	6.2	3.8	7.6
Delaware & Hudson	157	109	152	110	134	132	246	239	317	294	386	310	5.1	3.5	4.9	3.5	4.3	4.3
Delaware,Lackawanna & Western	99	65	81	71	77	79	191	145	196	171	202	160	3.4	2.2	2.8	2.5	2.7	2.7
Detroit & Mackinac	52	109	104	93	88	97	67	98	106	101	124	99	3.1	3.7	3.5	3.1	2.9	3.3
Detroit & Toledo Shore Line	140	92	43	72	53	80	265	205	96	170	138	175	4.7	3.0	1.4	2.4	1.7	2.6
Erie	86	79	88	71	62	77	140	158	216	177	160	170	2.9	2.6	3.0	2.4	2.1	2.6
Grand Trunk Western	160	148	146	142	140	147	258	275	317	327	365	308	5.1	4.7	4.6	4.5	4.4	4.7
Lehigh & Hudson River	35	164	92	98	99	98	81	458	273	288	307	281	1.3	6.1	3.4	3.7	3.7	3.6
Lehigh & New England	53	54	48	59	60	55	114	113	121	159	17[illegible]	[illegible]	1.8	1.8	1.6	1.9	2.0	1.8
Lehigh Valley	86	74	109	74	79	81	120	166	266	189	252	198	2.0	2.5	3.7	2.5	3.0	2.7
Monon,ahels	195	147	130	96	91	132	351	337	313	220	237	292	6.7	5.0	4.4	[illegible]	3.1	4.5
Montour	88	70	81	100	78	83	210	129	169	213	172	179	3.0	2.4	2.8	4.5	2.7	2.9
New York Central	131	131	150	118	100	126	238	268	352	286	[illegible]	282	4.3	4.2	4.9	3.9	3.2	4.2
New York,Chicago & St.Louis	143	132	176	156	151	152	262	265	427	359	409	44	4.5	4.2	5.6	4.9	4.8	4.8
New York,Ontario & Western	17	8	6	7	8	6	30	18	14	4	1	13	0.4	0.2	0.2	0.1	8	0.2
New York,Susquehanna & Western	58	54	46	32	33	45	47	62	78	62	79	66	2.0	1.8	1.6	1.1	1.1	1.5
Pere Marquette	168	169	152	130	83	140	260	272	297	281	193	261	5.6	5.6	5.1	4.3	2.8	4.7
Pittsburgh & Lake Erie	114	98	101	93	102	102	236	239	239	233	234	236	3.8	3.3	3.4	3.1	3.4	3.4
Pittsburg & Shawmut	197	181	206	164	175	185	448	454	586	507	524	504	7.0	6.4	7.3	5.8	6.2	6.5
Pittsburgh & West Virginia	252	171	123	105	110	152	507	382	338	325	343	379	8.3	5.6	4.0	3.5	3.6	5.0
Pittsburg,Shawmut & Northern	72	123	108	35	7	69	82	175	154	48	13	[illegible]	[illegible]	4.2	3.7	1.2	0.2	2.4
Wabash	140	126	118	111	103	120	225	211	236	238	252	[illegible]	4.5	4.1	3.8	3.6	3.3	3.9
Total	123	118	131	107	96	115	216	233	303	257	252	[illegible]	4.0	3.8	4.3	3.6	3.2	3.8
CENTRAL EASTERN REGION:																		
Akron,Canton & Youngstown	250	226	218	221	269	237	412	406	396	426	563	441	8.7	7.8	7.6	7.7	9.3	8.2
Baltimore & Ohio	151	200	191	144	123	162	268	428	422	312	[illegible]	341	5.1	7.0	6.7	5.1	4.3	5.7
Bessemer & Lake Erie	83	57	40	30	30	48	181	147	114	92	97	[illegible]	2.7	1.6	1.3	1.0	1.0	1.6
Central R.R.of New Jersey	83	77	104	84	132	96	165	175	250	204	323	[illegible]	2.9	2.7	3.7	3.0	4.7	3.4
Central R.R.of Pennsylvania &	-	-	-	-	68	*	-	-	-	-	170	*	-	-	-	-	2.4	*
Chicago & eastern Illinois	109	118	128	118	142	123	138	208	220	256	324	229	3.5	3.8	4.1	3.7	4.6	3.9
Chicago & Illinois Midland	125	196	150	129	34	159	313	440	431	1076	94	[illegible]	4	5.2	5.0	11.1	1.2	5.3
Chic,e,Indpls.& Louisville	79	58	66	53	72	65	95	76	105	94	156	[illegible]	[illegible]	1.9	2.1	1.6	[illegible]	2.1
Detroit,Toledo & Ironton	58	55	47	47	60	53	79	80	77	90	127	[illegible]	2.0	1.9	1.8	1.6	2.1	1.8
Elgin,Joliet & Eastern	149	83	146	90	99	113	234	153	290	192	218	17	4.8	2.7	4.7	2.9	3.4	3.7
Illinois Terminal	85	80	87	89	61	84	110	109	137	159	[illegible]	[illegible]	2.8	2.7	2.9	3.0	2.7	2.8
Long Island	93	146	210	123	87	132	200	356	664	361	270	[illegible]	[illegible]	5.1	7.4	4.3	3.0	4.6
Missouri-Illinois	248	211	219	175	191	209	322	335	411	312	393	[illegible]	7.9	6.7	7.0	5.6	6.1	6.7
Pennsylvania	111	97	101	109	92	102	185	190	233	252	229	[illegible]	3.9	3.4	3.5	3.8	3.2	3.6
Penna.-Reading Seashore Lines	76	74	83	78	92	81	190	185	216	222	276	[illegible]	2.9	2.7	3.0	2.9	[illegible]	3.0
Reading Co.	88	104	145	122	111	114	176	217	345	292	289	[illegible]	3.2	3.8	4.7	4.4	4.0	4.0
Staten Island Rapid Transit	66	70	61	65	108	74	142	160	155	162	270	[illegible]	[illegible]	2.6	[illegible]	2.7	4.2	2.8
Western Maryland	120	102	109	75	72	96	207	[illegible]	248	171	183	[illegible]	4.2	3.5	3.8	2.6	[illegible]	3.3
Wheeling & Lake Erie	204	121	94	94	93	121	319	211	214	223	220	[illegible]	6.6	4.0	[illegible]	3.1	3.1	4.0
Total	119	121	127	115	102	117	204	[illegible]	[illegible]	261	245	248	4.2	4.2	4.4	4.0	3.5	4.1
POCAHONTAS REGION:																		
Chesapeake & Ohio	83	96	100	97	98	95	120	155	200	[illegible]	242	156	2.7	3.1	3.2	3.1	3.2	3.1
Norfolk & western	45	69	66	68	86	67	66	112	124	144	191	127	1.4	2.2	2.1	[illegible]	2.8	2.1
Richmond,Fred.& Potomac	402	294	183	[illegible]	98	238	711	508	400	469	[illegible]	490	14.1	10.5	6.4	7.4	3.4	8.3
Virginian	97	101	[illegible]	89	81	95	137	166	186	[illegible]	452	260	[illegible]	[illegible]	[illegible]	[illegible]	2.6	[illegible]
Total	80	93	90	89	91	89	121	155	176	190	[illegible]	171	[illegible]	3.0	2.9	2.5	3.0	2.9
SOUTHERN REGION:																		
Alabama Great Southern	86	97	132	214	227	151	156	207	316	525	[illegible]	360	2.8	3.2	4.4	7.1	7.5	5.[illegible]
Atlanta & West Point	250	202	201	278	214	224	368	363	408	611	506	451	6.1	6.5	6.9	[illegible]	6.9	7.4
Atlantic Coast Line (Inc.ASAC)	152	172	182	271	286	213	224	321	361	568	[illegible]	[illegible]	[illegible]	5.9	6.4	9.2	[illegible]	7.[illegible]
Central of Georgia	167	147	147	144	154	152	268	214	241	240	298	236	5.6	5.0	5.0	4.9	5.2	5.1
Charleston & Western Carolina	191	184	182	270	197	199	224	278	264	600	[illegible]	401	5.6	6.4	[illegible]	9.5	6.8	6.9
Cincinnati,New Orleans & Tex.Pac.	48	44	56	74	93	63	88	85	143	180	241	147	1.6	1.4	1.9	2.5	3.2	2.1
Clinchfield	193	172	130	151	173	164	254	296	211	277	340	276	6.3	5.7	4.2	5.0	5.7	5.4
Columbus & Greenville	170	179	167	174	154	169	224	318	345	364	344	319	5.4	5.7	5.5	5.5	4.9	5.4
Florida East Coast	177	154	183	156	178	170	309	293	414	383	490	370	6.2	5.2	6.4	5.4	6.2	5.9
Georgia R.R.	236	270	212	200	126	209	376	432	422	400	287	[illegible]	7.7	8.8	[illegible]	6.5	4.2	6.8
Georgia & Florida	307	255	117	195	253	271	261	253	331	258	396	300	11.4	10.5	11.8	7.2	9.4	10.1
Georgia,Southern & Florida	128	141	113	143	155	144	162	207	180	238	324	224	4.1	4.5	3.6	4.6	6.6	4.6
Gulf,Mobile & Ohio	337	277	294	274	215	279	499	499	596	560	471	525	10.6	8.7	9.3	8.6	6.8	8.[illegible]
Illinois Central (Inc.G&SI and YAMV)	213	202	241	203	208	213	280	331	453	424	472	392	7.6	6.6	7.9	6.6	6.8	7.[illegible]
Louisville & Nashville	164	159	230	134	130	145	243	326	446	272	287	[illegible]	[illegible]	6.6	4.7	4.2	4.2	[illegible]
Mississippi Central	204	150	122	136	98	142	279	247	252	297	211	257	7.2	[illegible]	[illegible]	4.2	[illegible]	4.7
Nashville,Chattanooga & St.Louis	122	230	208	176	123	172	184	382	425	383	286	[illegible]	4.5	8.4	7.6	6.5	4.5	6.[illegible]
New Orleans & Northeastern	119	147	207	250	239	192	208	304	519	680	651	472	[illegible]	4.8	7.1	8.7	8.1	6.6
Norfolk Southern	355	320	272	224	255	285	330	387	439	419	[illegible]	[illegible]	12.5	[illegible]	9.3	7.7	8.8	[illegible]
Seaboard Air Line	126	191	207	186	175	189	266	336	432	388	404	[illegible]	[illegible]	[illegible]	6.9	[illegible]	[illegible]	6.2
Southern Ry.	176	153	154	136	152	150	340	304	350	32[illegible]	386	[illegible]	[illegible]	[illegible]	[illegible]	4.4	4.4	4.9
Tennessee Central	329	213	151	139	137	164	451	344	287	257	275	[illegible]	10.9	7.0	[illegible]	4.6	4.5	6.4
Western Ry.of Alabama	232	242	250	235	183	228	334	403	480	485	426	4.4	7.6	7.9	[illegible]	7.7	6.0	7.5
Total	186	186	187	187	186	186	269	318	372	397	437	359	[illegible]	6.2	[illegible]	[illegible]	[illegible]	6.2

Table B

NUMBER AND AGGREGATE COST OF NEW WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOODEN TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of the five years 1942 to 1946, inclusive

Note: All figures are exclusive of bridge and switch ties

Table B

NUMBER AND AGGREGATE COST OF NEW WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOODEN TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of the five years 1942 to 1946, inclusive

Note: All figures are exclusive of bridge and switch ties

Road	Number of new wooden cross tie renewals per mile of maintained track						Aggregate cost of new wooden cross tie renewals per mile of maintained track						Per cent new wooden cross tie renewals to all ties in tracks					
	1942	1943	1944	1945	1946	5 year average	1942	1943	1944	1945	1946	5 year average	1942	1943	1944	1945	1946	5 year average
NORTH-WESTERN REGION:																		
Chicago & North Western	136	89	108	143	121	119	$152	$121	$192	$267	$240	$194	4.6	3.0	3.6	4.8	4.1	4.0
Chicago Great Western	136	120	180	127	155	144	194	188	341	266	370	272	4.6	4.0	6.1	4.3	5.2	4.8
Chicago, Milwaukee, St.Paul & Pac.	172	145	161	157	109	149	219	226	279	297	213	247	5.6	4.7	5.2	5.1	3.5	4.8
Chicago, St. Paul, Minneap. & Omaha	173	114	133	142	112	135	210	187	256	307	253	247	5.9	3.8	4.5	4.8	3.8	4.6
Duluth, Missabe & Iron Range	105	127	89	66	64	90	153	225	185	134	133	166	3.5	4.2	3.0	2.6	2.2	3.0
Duluth, South Shore & Atlantic	174	145	147	148	142	151	155	157	224	258	273	213	6.1	5.1	5.0	4.6	4.7	5.1
Duluth, Winnipeg & Pacific	330	356	342	347	295	334	356	520	682	609	521	538	11.3	12.1	11.6	11.8	10.0	11.4
Great Northern	150	156	169	149	96	144	212	279	330	286	177	257	4.8	5.1	5.5	4.8	3.1	4.7
Green Bay & Western	299	212	392	225	142	254	365	368	793	490	318	467	10.4	7.4	13.6	7.2	4.9	8.7
Lake Superior & Ishpeming	175	77	134	171	151	142	144	100	213	293	310	212	5.8	2.6	4.5	5.7	5.0	4.7
Minneapolis & St.Louis	216	117	135	144	111	145	217	152	221	256	209	211	7.2	3.9	4.2	4.8	3.7	4.8
Minneapolis, St.Paul & S.S.Marie	126	86	84	92	104	98	128	120	147	178	201	155	4.3	2.9	2.9	3.1	3.5	3.3
Northern Pacific	139	119	107	90	61	103	184	178	172	154	109	159	4.8	4.1	3.7	3.1	2.1	3.6
Spokane International	368	387	435	342	294	365	296	370	506	405	358	387	12.6	13.3	15.0	11.8	10.1	12.6
Spokane, Portland & Seattle	212	225	492	233	119	256	311	348	932	436	253	456	7.0	7.4	16.2	7.7	3.8	8.4
Total	153	127	144	136	104	133	192	197	258	257	203	221	5.1	4.2	4.8	4.5	3.4	4.4
CENTRAL WESTERN REGION:																		
Alton R.R.	194	177	181	189	247	198	288	281	363	431	643	401	6.4	5.9	6.0	6.2	8.2	6.5
Atchison, Topeka & Santa Fe	105	80	78	100	80	89	135	102	116	173	147	135	3.5	2.6	2.6	3.3	2.6	2.9
Chicago, Burlington & Quincy	193	185	182	169	126	171	267	278	336	319	258	292	6.2	6.0	5.9	5.5	4.1	5.5
Chicago, Rock Island & Pacific	110	117	165	140	109	128	119	140	331	292	236	224	3.7	3.9	5.5	4.7	3.6	4.3
Colorado & Southern	93	111	99	103	103	102	123	190	188	205	122	186	3.1	3.7	3.3	3.4	3.4	3.4
Colorado & Wyoming	103	64	69	56	40	66	196	178	195	169	117	171	3.7	2.2	2.4	2.0	1.4	2.3
Denver & Rio Grande Western	33	29	40	40	35	35	45	49	74	83	77	66	1.1	0.9	1.3	1.3	1.1	1.1
Denver & Salt Lake	229	125	229	159	169	152	400	257	691	354	384	417	7.5	4.1	7.6	5.3	5.3	6.0
Fort Worth & Denver City	62	99	117	114	153	113	110	163	174	235	329	202	2.7	3.3	3.9	3.8	5.1	3.8
Northwestern Pacific	215	231	297	237	142	224	295	384	516	413	251	368	7.4	8.0	10.2	8.2	4.9	7.4
Southern Pacific Co.- Pac.Lines	106	115	150	160	77	122	145	175	256	283	141	200	3.5	3.7	4.8	5.1	2.5	3.9
Toledo, Peoria & Western	112	95	61	*	*	*	156	135	107	*	*	*	3.5	3.0	1.9	*	*	*
Union Pacific	196	164	160	140	70	146	237	223	246	232	123	212	6.9	5.8	5.7	4.9	2.5	5.2
Utah Ry.	87	69	52	66	85	72	212	168	122	157	214	175	3.1	2.4	1.8	2.3	3.0	2.5
Western Pacific	135	164	293	264	123	196	178	238	517	408	247	330	4.5	5.5	9.8	8.8	4.1	6.6
Total	136	125	139	136	93	126	176	177	242	250	185	206	4.5	4.1	4.6	4.5	3.1	4.2
SOUTH-EASTERN REGION:																		
Beaumont, Sour Lake & Western	152	192	255	157	182	188	199	317	484	309	395	341	5.1	6.4	8.6	5.3	6.1	6.1
Burlington-Rock Island	62	73	95	84	137	90	67	65	117	133	292	135	1.9	2.1	3.0	2.7	4.4	2.8
International-Great Northern	131	112	102	123	142	122	166	169	170	247	315	217	4.4	3.7	3.4	4.1	4.7	4.1
Kansas City Southern	476	409	251	83	56	255	626	650	439	161	113	398	15.0	12.9	7.9	2.6	1.8	8.0
Kansas, Oklahoma & Gulf	37	48	60	36	55	47	43	72	104	67	116	80	1.2	1.6	2.0	1.2	1.9	1.6
Louisiana & Arkansas	528	718	448	130	25	370	676	1180	732	255	51	599	16.3	22.1	13.7	4.0	0.8	11.4
Midland Valley	56	61	66	34	61	56	65	88	99	62	126	88	1.9	2.1	2.3	1.2	2.1	1.9
Missouri & Arkansas	332	355	384	344	99	303	227	353	573	454	145	350	10.7	11.4	12.3	11.0	3.2	9.7
Missouri-Kansas-Texas Lines	122	324	325	137	92	244	471	549	630	323	196	434	10.2	10.3	10.3	5.0	2.9	7.7
Missouri Pacific	146	105	95	90	110	109	181	147	160	159	226	175	4.7	3.4	3.1	2.9	3.6	3.5
New Orleans, Texas & Mexico	106	301	168	113	137	177	213	242	336	222	300	263	5.4	9.8	5.5	3.7	4.2	5.8
Oklahoma City-Ada-Atoka	311	158	287	233	248	247	286	256	248	433	522	349	10.8	5.5	10.0	8.1	8.6	8.6
St.Louis, Brownsville & Mexico	154	153	186	146	157	159	200	249	354	276	334	283	5.1	5.1	6.2	4.8	5.4	5.3
St.Louis-San Francisco	122	132	132	107	111	121	148	186	208	172	212	185	3.9	4.2	4.2	3.4	3.5	3.8
St.Louis, San Fran. Texas	116	104	91	61	122	99	132	135	139	97	226	146	3.7	3.3	2.9	2.0	3.9	3.2
St.Louis Southwestern Lines	159	168	206	196	158	177	215	274	380	389	338	319	4.9	5.3	6.5	6.2	5.1	5.6
San Antonio, Uvalde & Gulf	101	113	172	114	145	129	126	159	194	210	319	202	3.5	3.9	6.0	4.0	5.2	4.5
Texas & New Orleans	149	110	128	122	115	125	156	130	201	197	221	181	5.5	4.0	4.7	4.4	4.1	4.7
Texas & Pacific	211	202	232	192	161	216	266	365	411	370	325	347	7.2	9.0	7.9	6.6	6.2	7.4
Texas Mexican	174	104	104	144	79	121	272	178	187	266	170	215	5.5	3.3	3.5	4.5	4.5	3.9
Total	187	179	169	124	115	155	236	265	293	224	230	250	6.2	5.9	5.5	4.1	3.8	5.1
Grand Total, United States	145	136	144	132	113	134	206	226	280	269	251	246	4.8	4.5	4.8	4.4	3.8	4.5
CANADIAN ROADS:																		
Canadian National	192	170	165	159	154	168	186	187	217	240	246	215	6.6	5.8	5.6	5.4	5.3	5.7
Canadian Pacific	139	141	145	149	149	145	146	168	206	228	251	200	4.9	4.9	5.1	5.2	5.2	5.1
Ontario Northland [c]	228	176	200	200	205	202	171	144	180	294	252	208	7.9	6.1	6.9	6.6	7.1	6.9

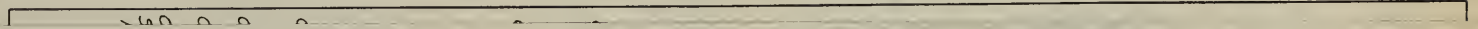
* Not reported.

[a] See notes [b] and [c], Table A.

[b] The Central Railroad of Pennsylvania started operations August 5, 1946, formerly part of Central R.R. of New Jersey.

[c] Formerly Temiskaming & Northern Ontario Ry.

Compiled by
Association of American Railroads, Bureau of Railway Economics, Washington, D.C.
from annual reports of Class I railways to the Interstate Commerce Commission.
June 23, 1947



5670-2

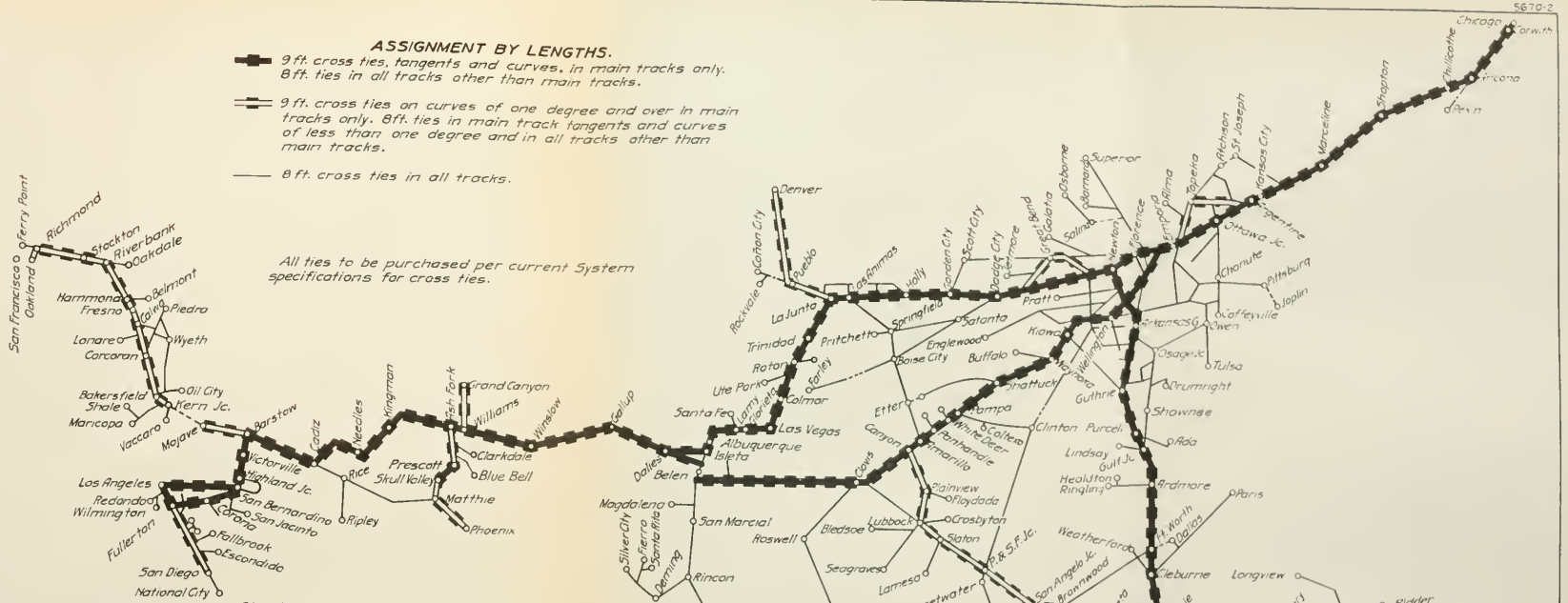
ASSIGNMENT BY LENGTHS.

9 ft. cross ties, tangents and curves, in main tracks only. 8 ft. ties in all tracks other than main tracks.

9 ft. cross ties on curves of one degree and over in main tracks only. 8 ft. ties in main track tangents and curves of less than one degree and in all tracks other than main tracks.

8 ft. cross ties in all tracks.

All ties to be purchased per current System specifications for cross ties.



CLASSES OF TIES

Class 1-9 Ties 9 ft long treated. Sound ties, all woods, 7"x8" hewn and 7"x9" sawn, or larger, 8"x10" maximum.

Class 1 Ties 8 ft. long treated. Sound ties, all woods, 7"x8" or larger but not exceeding 8"x10" cross section.

Class 2 Ties 8 ft. long treated. Sound ties, all woods, less than 7"x8" down to and including 6"x8" cross section, also Class 1 ties degraded on account of some slight imperfections.

Class 3 Ties 8 ft. long treated. Acceptable by-product, sound woods, not less than 6" thick, not less than 7" face, not less than 8" through the body of the tie. Also degrades from Class 1 and Class 2 ties.

Special "X" Ties, 8 ft. long treated. These ties are so classified on account of slight "heart rot" or "sap rot."

Rejects (not treated) from above classes 8 ft lg.

ASSIGNMENT BY CLASSES

Class 1-9 Ties – To be used in main tracks in that portion of Class "A" track at sheet 1 shown ▬ above and in main tracks on curves of one degree and over in that portion of Class "A" track of sheet 1 shown ═ above.

Class 1 Ties – To be used in all Class "A" main tracks not included in above Class 1-9 tie territory.

Class 2 Ties – To be used in all Class "B" main tracks, and in important yard leads.

Class 3 Ties or Special "X" Ties – To be used in passing, side and industry tracks of Class "A" and Class "B" territory.

Rejects – To be used only in especially authorized locations.

If sufficient number of ties for above assignment is not available, ties of the next higher class may be used.

TABLE SHOWING MAINTAINED MILEAGE AS OF JAN. 31, 1942

Groups	MAIN TRACKS Softwood Class 1-9	Softwood Class 1	Softwood Class 2	Hardwood Class 1-9	Hardwood Class 1	Hardwood Class 2	Side Tracks Cl. 3 & "X"	Total Miles of Track Maintained
Southern pine *	1917	1066	3177	457	174	417	2663	9871
Southern pine or Arizona-New Mexico pine *	350	198	732	64	—	67	496	1907
Arizona-New Mexico pine *	862	263	1419	212	—	121	1106	3983
Douglas fir or Arizona-New Mexico pine *	965	338	77	395	22	39	490	2326
Douglas fir *	332	435	1366	231	4	75	—	2386
Grand Total	4426	2300	6771	1359	200	719	4755	20530

* Classification of track symbols per sheet 1.

This sheet and sheet 1 supersede C.E.S. No 5670, dated Mar 1935

REVISIONS OR ADDITIONS

Date	Changed Items	Approved
2-1942	9' tie territory and mileage	G.W.N.

THE A. T. & S. F. RY. SYSTEM

STANDARD

CROSS TIES

ASSIGNMENT BY LENGTHS AND CLASSES

C.E.S. NO 5670, SHEET 2 OF 4 CHICAGO, JAN. 1940

APPROVED: VICE PRESIDENT

APPROVED: CHIEF ENG'R SYSTEM

The 9-Ft. Cross Tie on the Santa Fe System

By G. W. HARRIS
Chief Engineer System, Atchison, Topeka & Santa Fe Railway

The adoption of the 9-ft. cross tie as standard on the Santa Fe in 1938 was in my opinion one of the most important improvements that has been made to the track structure of our high speed and heavy traffic lines in many years. With the advent of high speed and heavier wheel loads, our study developed the need for additional rail support, increased tamping area, and greater resistance to lateral thrust. It was a matter of bringing our track structure up to present day requirements.

In the program of railroad track construction, there have been improvements in design and increase of weight of rail; all the various fastenings have been improved; and since the early days when no tie plates of any kind were used, tie plates have increased in size and improved in design. The exception to all of these improvements in track structure was the cross tie, which, while it has ben made resistant to decay by preservative treatment, had changed little as to size or length.

We started our investigation of cross tie sizes on the Santa Fe in 1922, and at that time we adopted the 7 by 8 by 8-ft. tie as standard for main line tracks. In 1934 we again investigated this matter, and in 1935 went to a 7 by 8 by 8-ft. 6-in. tie for curves of one degree and over, and for both curves and tangents in our important main tracks in certain mountainous territories. In November 1938, the 7 by 9 by 9-ft. tie was adopted as standard for tangents and curves in our most important main tracks and for curves of one degree and over in certain less important main tracks.

From our study of the question of tie length, the conclusions reached have been in harmony with those of the AREA Tie committee and the Special Committee on Stresses in Railroad Track. The first report of the Tie committee on length of cross ties, which was made in 1905, argued for a longer tie, as did succeeding reports. In the 1940 report the committee commented: "It is believed this (the 9-ft. tie) will result in ultimate economy, as well as stronger track." With this statement I am in hearty accord. Increased tamping area possible with the 9-ft. tie means that a 9-ft. tie will have 43 percent more effective bearing area than an 8-ft. tie of the same width; and to again quote the Tie committee, I firmly believe in the statement made in the 1939 report of that committee: "An increase in the supporting power of the roadway may be obtained by the increase in the length of ties at less expense than by any other means."

War conditions resulted in inability to secure our entire requirements, and it was necessary to conserve the 9-ft. ties produced, for line changes and other out of face insertions. However, since the 9-ft. tie was made standard in 1938, 2½ million have been inserted in our tracks; and during the past year we have been able to purchase greatly increased proportions of the 9-ft. ties. We do not as yet have sufficient out of face mileage of 9-ft. ties on which to develop the saving in labor cost of surfacing and lining as compared to similar track on 8-ft. ties; but I am satisfied that at the present high track labor rates, the increased cost of labor to surface and line track on 8-ft. ties will be greatly in excess of the increased cost of 9-ft. ties per mile per year.

The 9-Ft. Cross Tie on the Atlantic Coast Line Railroad

By R. S. GROOVER
Chief Engineer, Atlantic Coast Line Railroad

We adopted the 9-ft. cross ties in 1941 and since that date, up to and including September 30, 1947, we purchased a total of 10,512,995 cross ties for all purposes. At the beginning we could only secure a small percentage of our ties in the 9-ft. length and at present are only securing about 65 percent in this length. Our records are kept in such a manner that I cannot give you exact figures on number of 9-ft. ties purchased.

Our prices for cross ties are based on 9-ft. length and we pay 5 cents less per tie when the 8-ft. 6 in. ties are furnished.

When the center section of a cross tie rests firmly on compacted ballast and transfers rail pressures equally with the remainder of the bearing area of the tie, there soon develops a condition commonly known as center bound track to which is attributable poor riding and distortion of line and surface of the rails. This condition is avoided by leaving untamped a section at the center of the track. With shorter ties, in order to balance inner and outer support of the rail, the untamped center section is greater than with longer ones. A 6-in. increase in the length of the ties used adds 12-in. to the available supporting length to be tamped, as the same amount of supporting area can be added on the inside as on the outside of the rail for balanced support. Therefore, where center bound track is an eventual certainty with 8-ft. cross ties, it is not nearly so likely to occur with 9 ft. ties, which provides 2 ft. additional available tamping length for balanced support of the rail. It is also true that 9-ft. cross ties, well tamped, give more stable resistance to the forces that tend to distort the line and surface of the track than the shorter ones produce. These qualities result in reduced labor, maintenance and operating economies in favor of the longer ties, and also make for smoother riding conditions at high speeds.

There has been some criticism of the change to a longer tie because of the irregular line of the tie ends that will result during the transition period. However, it has been our standard practice to maintain a ballast section three inches beyond the ends of the ties in order to obtain bearing support as near as possible to the end of the tie to add resistance to side pressure in the track. This section tends to make irregularities of length less noticeable than in lighter ballast dress. Even where the ends are exposed to view the advantages of the 9-ft. ties are too great to withhold its adoption because of unsightly conditions during the transition period.

Report of Committee 8—Masonry

F. R. Smith, *Chairman,*
A. J. Boase
M. W. Bruns
J. R. Burkey
L. T. Casson
Maurice Coburn
C. C. Cooke
G. H. Dayett
H. A. Dise
G. F. Eberly
H. J. Engel
J. A. Erskine
A. B. Fowler
W. J. Galloway
W. P. Geiser
R. W. Gilmore
R. L. Groover
O. E. Hager
R. Hayes
Meyer Hirschthal
A. C. Johnson
J. E. Kalinka
A. P. Kouba
J. A. Lahmer
A. N. Laird
J. F. Leonard
C. P. Marsh
R. L. Mays
E. A. McLeod
G. A. McRoberts
L. M. Morris
M. Nearing
L. H. Needham
M. S. Norris
B. J. Ornburn
Roscoe Owen
G. H. Paris
R. B. Peck
H. Posner
W. R. Prass
C. B. Porter,
Vice-Chairman,
R. V. Proctor
W. M. Ray
J. L. Rippey
G. E. Robinson
E. T. Rucker
C. P. Schantz
Everett Scroggie
J. H. Shieber
D. H. Shoemaker
C. H. Splitstone
Neil Van Eenam
Jamison Vawter
K. J. Wagoner
C. A. Whipple
W. Wilbur
W. R. Wilson
E. P. Wright

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Review of current literature pertaining to masonry work.

   No report.

3. Principles of design of masonry structures, collaborating with Committees 1, 5, 6, 7, 13, 15, 28, 29 and 30.

   Specifications for design of concrete transmission poles, presented for adoption and publication in the Manual ..... page 244
   Report on crib walls, presented as information ..... page 244
   Report on reinforced concrete culvert pipe, presented as information ..... page 251

4. Design and construction of foundations for masonry structures, including spread footings, piling, or other special construction which supports the structure and its loads, collaborating with Committees 1, 6, 7, 15 and 30.

   Report on pile foundations, presented as information ..... page 254

5. Earth pressure as related to masonry structures.

   No report.

6. Methods of designing, constructing, and maintaining tunnels, collaborating with Committees 1, 5, 28 and 29.

   Report on lining railway tunnels with timber, presented as information ... page 264

AREA Bulletin 471, January 1948.

7. Masonry repairs, including solidification by internal pressure grouting and surface maintenance by various methods.

No report.

8. Methods for improving the quality of concrete and mortars, collaborating with Committee 6.

No report.

9. Specifications for the construction and maintenance of masonry structures.

No report.

The Committee on Masonry,
F. R. Smith, *Chairman.*

Report on Assignment 3

Principles of Design of Masonry Structures, Collaborating with Committees 1, 5, 6, 7, 13, 15, 28, 29 and 30

B. J. Ornburn (chairman, subcommittee), A. J. Boase, H. A. Dise, Meyer Hirschthal, J. E. Kalinka, A. N. Laird, W. R. Prass, Everett Scroggie.

Part 1—Concrete Transmission Poles

Last year your committee presented as information, tentative specifications for design of concrete transmission poles with an urgent request for critical review, comments, and criticism so that they could be constructively amended before offering them for adoption and publication in the Manual. During the past year, no comments have been received with respect to these specifications, and accordingly, they are offered this year identically as they appear in the Proceedings, Vol. 48, 1947, pages 449–454, incl., to replace the specifications now included on page 8–75.

Part 2—Crib Walls

Your committee was requested to promptly prepare specifications for cribbing to be incorporated in Chapter 8 of the Manual, and because of the necessity of performing this work in the shortest possible time, a special subcommittee was appointed consisting of Mr. Dayett, chairman, and Messrs. Eberly, McRoberts, and Posner. The following specifications are presented as information for the coming year so that the Association may have an opportunity to review and criticize them prior to offering them a year hence for adoption and publication in the Manual.

A. SPECIFICATIONS FOR REINFORCED CONCRETE CRIBBING

1. Design

Crib walls shall be assumed to act as a unit and shall be designed to resist the overturning and sliding forces specified in cases 1, 2, 3, 7, 8 and 9, of the AREA Specifications for the Design of Retaining Walls.

The wall section resisting overturning shall be taken as a rectangle having a height equal to the total height of the crib and a depth equal to the distance between the faces of the front and rear stretchers.

The weight of the crib section within these limits, (including the weight of the crib members), shall be assumed to be of unit weight equal to that of the compacted filling material.

Low walls (4 ft. high and under) may be made with a plumb face. In general, walls shall be battered on the face at least 2 in. per ft. For high walls (12 ft. high and over) the batter shall be increased or supplemental cribs shall be added at the back so that the structure as a whole will be in equilibrium with the forces tending to overturn it. Crib walls shall generally not exceed 21 ft. in height.

Track shall be so located that no live load will be borne by the top members of the crib wall.

The crib units, both stretchers and headers, shall be so designed that they will resist the bending and shearing stresses imposed on them and shall provide adequate bearing. They shall be rectangular in cross section with all exposed edges beveled.

The crib units shall be reinforced with deformed steel bars at least ⅜ in. diameter. The area of reinforcement for each unit shall be not less than 0.9 percent of its gross cross-sectional area.

The headers and stretchers shall be designed so that when assembled in a wall they will bear at two points only, forming a cellular structure that will be flexible enough to take a reasonable amount of settlement.

In open face cribs, the space between stretchers shall not exceed 8 in. so as to properly retain the fill.

Expansion joints shall be provided at intervals not to exceed 90 ft. The crib cells on either side of the expansion joint shall be provided with independent headers on the side adjoining the joint. All stretchers and sill pieces shall be terminated flush with the outside face of these headers.

2. Manufacture

(a) *General.*—The materials, proportioning and workmanship shall conform to the AREA Specifications, Section I, Chapter 8, with the following modifications:

1. *Aggregates.*—The maximum size of coarse aggregate shall not be more than 1 in.

2. *Class of Concrete.*—The concrete shall be class 3700 using not more than 5½ gal. of water per sack of cement.

3. *Workability and Placement.*—The mixture shall be of workable consistency dependent on the method of placement to insure complete embedment of reinforcing and prevent honeycombing. Vibrating equipment shall preferably be used in the manufacturing process.

4. *Curing.*—Wet curing shall be begun as soon as possible after completion of placement of the concrete and shall comply with the wet curing paragraphs of the specifications.

(b) *Defects.*—All members shall be free of depressions and of spalled, patched or plastered surfaces or edges or other defects that may impair strength or durability.

(c) *Handling.*—Members shall be handled carefully, avoiding dropping or severe jarring. Any cracks or otherwise defective members will be rejected.

(d) *Locking Devices.*—Effective locking devices shall be provided by the manufacturer. They shall be of a type which will permit of a slight movement in the wall without causing any damage to the crib units. If used, dowels shall be of proper length and made of wrought iron or galvanized steel, and have a minimum diameter of ⅞ in.

round. Casings shall be made of galvanized steel or wrought iron pipe and have an inside diameter ¼ in. larger than the diameter of the dowel.

(e) *Alternates.*—Crib members and their arrangement shall be as shown on the plans, provided however, that members may be purchased from manufacturers with the approval of the engineer. Such members shall be of equivalent design and the contractor must submit detailed specifications and plans for approval before delivery of any alternate material.

3. Installation

(a) *Preparing Base.*—The foundation or bed for the cribbing shall be firm and shall be approved by the engineer before any cribbing is placed.

The foundation shall be sloped at a right angle to the batter on the face of the finished crib.

(b) *Placing Cribbing.*—Longitudinal concrete stretchers shall be used to support the lower cribbing course, particularly at the front face.

All members shall be secured together by means of effective locking devices.

Crib members shall be carefully handled and erected in such a manner as to avoid any injury due to shock or impact. Any member which becomes cracked or otherwise injured during erection shall be completely removed and replaced.

(c) *Filling.*—The filling of the interior of the crib shall follow closely the erection of the successive tiers of units and at no time shall the wall be laid up higher than 3 ft. above the backfilled portion.

Approved fill material of crushed stone or other coarse granular material, rock (12 in. maximum dimension), or a combination of these shall be placed in layers not exceeding 12 in. in thickness and tamped or consolidated in a satisfactory manner. Care shall be used in placing rock filling material so as to avoid damaging or dislodging the cribbing members. The puddling method of filling shall not be used. All vegetable matter shall be excluded from the filling material. Clay or material having a large percentage of clay shall not be used as fill. The fill and backfill material shall not contain any element detrimental to concrete.

In open face cribbing a layer of hand placed stone shall be placed in back of the front members of the cribbing to prevent loss of fill through the openings.

B. SPECIFICATIONS FOR METAL CRIBBING

1. Design

Crib walls shall be assumed to act as a unit and shall be designed to resist the overturning and sliding forces specified in cases 1, 2, 3, 7, 8 and 9, of the AREA Specifications for the Design of Retaining Walls.

The wall section resisting overturning shall be taken as a rectangle having a height equal to the total height of the crib and a depth equal to the distance between the faces of the front and rear stretchers.

The weight of the crib section within these limits, (including the weight of the crib members), shall be assumed to be of unit weight equal to that of the compacted filling material.

Low walls (4 ft. high and under) may be made with a plumb face. In general, walls shall be battered on the face at least 2 in. per ft. For high walls (12 ft. high and over) the batter shall be increased. Crib walls shall generally not exceed 21 ft. in height.

Track should be so located that no live load will be borne by the top members of the cribbing.

The crib units, both stretchers and headers, shall be so designed that they will resist the bending and shearing stresses imposed on them and shall provide adequate bearing.

The headers and stretchers shall be designed so that when assembled in a wall they will form a cellular structure that will be flexible enough to take a reasonable amount of settlement.

Expansion joints shall be provided at intervals not to exceed 90 ft. The crib cells on either side of the expansion joint shall be provided with independent headers on the side adjoining the joint. All stretchers and sill pieces shall be terminated flush with the outside face of these headers.

2. Manufacture

The sheets from which all members are manufactured shall be made of a base metal meeting the requirements for chemical composition and zinc coating specified in AREA Specifications for Corrugated Metal Culverts.

If specified by the engineer the crib members shall be bituminous coated in accordance with AREA Specifications for Bituminous Coated Corrugated Metal Pipe and Arches.

All members shall be prefabricated in the manufacturer's plant prior to shipment to the site.

Headers and stretchers upon assembly shall interlock or be joined together by means of flexible bolt or dowel connections. Bolts or dowels shall be of proper length and made of wrought iron or galvanized steel.

The various members shall be constructed of a base metal of not less than 16 gage for walls up to 10 ft. in height and of heavier gage for higher walls.

All members shall be straight and true before field assembly, and the galvanizing or other coating must not be damaged. Any bent or otherwise defective members will be rejected.

Crib members and their arrangement shall be as shown on the plans, provided however that members may be purchased from manufacturers with the approval of the engineer. Such members shall be of equivalent design and the contractor must submit detailed specifications and plans for approval before delivery of any alternate material.

3. Installation

(a) *Preparing Base.*—The foundation or bed for the cribbing shall be firm and shall be approved by the engineer before any cribbing is placed.

The foundation shall be sloped at a right angle to the batter on the face of the finished crib.

(b) *Placing Cribbing.*—Crib members shall be carefully handled and erected in such a manner as to avoid injury. Any member which becomes bent or otherwise injured during erection shall be completely removed and replaced.

(c) *Filling.*—The filling of the interior of the crib shall follow closely the erection of the successive tiers of units and at no time shall the wall be laid up higher than 3 ft. above the backfilled portion.

Approved fill material of crushed stone or other coarse granular material, rock (12 in. maximum dimension), or a combination of these shall be placed in layers not exceeding 12 in. in thickness and tamped or consolidated in a satisfactory manner. Care shall be used in placing rock filling material so as to avoid damaging or dislodging the cribbing members. The puddling method of filling shall not be used. All vegetable

matter shall be excluded from the filling material. Clay or material having a large percentage of clay shall not be used as fill. The fill and backfill material shall not contain any elements detrimental to metal.

In open face cribbing a layer of hand placed stone shall be placed in back of the front members of the cribbing to prevent loss of fill material through the openings.

(d) *Drainage.*—Provision must be made for drainage if necessary in back of and in cells of wall by means of French drains or other approved method.

C. SPECIFICATIONS FOR TIMBER CRIBBING

1. Design

Crib walls shall be assumed to act as a unit and shall be designed to resist the overturning and sliding forces specified in cases 1, 2, 3, 7, 8 and 9, of the AREA Specifications for the Design of Retaining Walls.

The wall section resisting overturning shall be taken as a rectangle having a height equal to the total height of the crib and a depth equal to the distance between the faces of the front and rear stretchers.

The weight of the crib section within these limits, (including the weight of the crib members), shall be assumed to be of unit weight equal to that of the compacted filling material.

Low walls (4 ft. high and under) may be made with a plumb face. In general walls shall be battered on the face at least 2 in. per ft. For high walls (12 ft. high and over) the batter shall be increased or supplemental cribs shall be added in back so that the structure as a whole will be in equilibrium with the forces tending to overturn it. Crib walls shall generally not exceed 21 ft. in height.

Track should be so located that no live load will be borne by the top members of the crib.

The crib units, both stretchers and headers, shall be so designed that they will resist the bending and shearing stresses imposed on them and shall provide adequate bearing. They shall be rectangular in cross section.

2. Materials

Timber used for cribbing shall be sawn or hewn timber and shall conform to the requirements of AREA Specifications for Structural Timbers. Timber shall be treated or untreated as specified by the engineer.

When treated timber is required, it shall be treated in accordance with specifications of Committee 17—Wood Preservation (AREA Manual).

If timbers are to be treated all framing indicated on the plans shall be completed before treatment. All framing shall be done in a workmanlike manner true to line and angle. When any field framing of treated material is required, all such framing and cuts shall receive a thorough coating of approved preservative immediately before assembly.

No timbers shall be less than 8 in. least dimension.

3. Installation

(a) *Preparing Base.*—The foundation or bed for the cribbing shall be firm and shall be approved by the engineer before any cribbing is placed.

The foundation shall be sloped at right angles to the batter on the face of the finished crib. See Fig. 1.

(b) *Mud Sills.*—When mud sills are used, they shall be set at right angles to the face of cribbing and bear firmly and evenly on the foundation material. See Fig. 1.

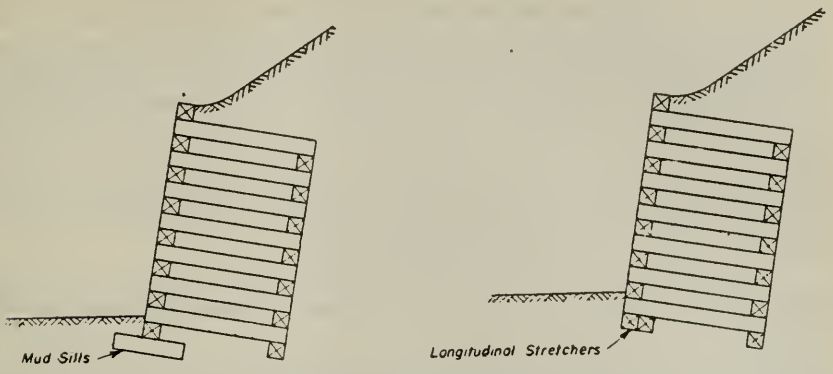


Fig. 1.—Typical Sections Through Crib Walls.

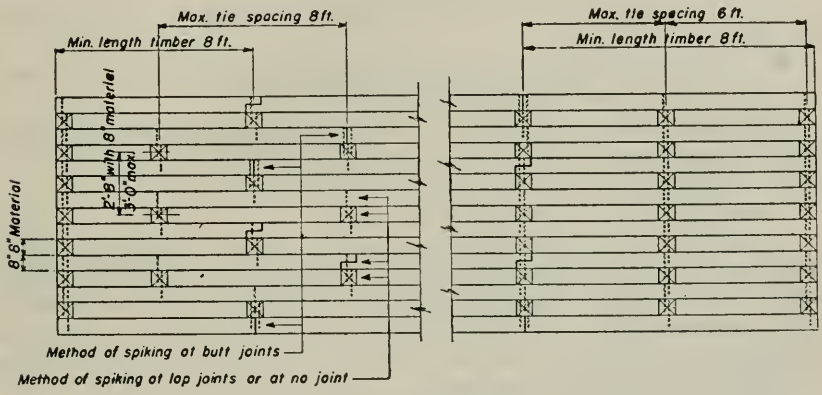
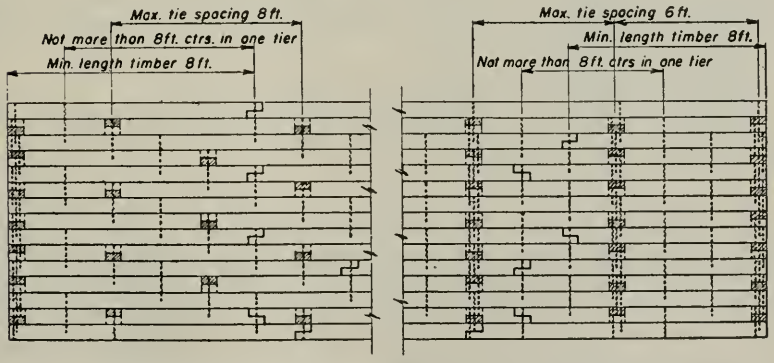

Max. tie spacing 8ft.
Min. length timber 8 ft.
2'-8" with 8" material
1'-0" max.
8"x8" Material
Max. tie spacing 6 ft.
Min. length timber 8 ft.
Method of spiking at butt joints
Method of spiking at lap joints or at no joint

Fig. 2.—Open Face Crib Walls.


Max. tie spacing 8ft.
Not more than 8ft. ctrs. in one tier
Min. length timber 8ft.
Max. tie spacing 6 ft.
Min. length timber 8ft.
Not more than 8ft. ctrs in one tier

Ties Staggered Ties in Line

Fig. 3.—Closed Face Cribbing.

Mud sills shall be not less than 8 in. by 8 in. in cross section, and not less than 3 ft. long. They shall be spaced as required to distribute the load properly to the foundation material, but in no case shall they be spaced more than 4 ft. center to center

Mud sills shall be leveled to fit the base tier of face timbers resting directly on them.

(c) *Face Timbers or Stretchers.*—The timbers in the base tier and in alternate tiers above the base shall be as long as practicable. Preferably they shall have a minimum length of 8 ft. Joints in each tier shall stagger with joints in adjacent tiers.

Crib faces shall be laid solid or open as indicated on the plans. For open face cribbing, a maximum of 8 in. opening will be allowed.

Care shall be exercised in the erection of cribs to produce a true and even face built to line as shown on the plans. All face timbers shall be set horizontal. See Figs. 2 and 3.

(d) *Ties or Headers.*—The length of ties shall be sufficient to develop the required anchorage, and in no case shall the length of a tie extending back from the face of crib be less than half of the height of fill above the tie in question.

Ties shall be anchored to the face by framing, drift bolting or by other approved methods.

Ties shall be anchored in the fill to cross pieces or stretchers fastened to them at right angles by drift bolts or other suitable means.

Ties shall be spaced not more than 8 ft. center to center in any horizontal tier and shall be staggered with the next adjacent tier of ties, or if ties are not staggered, they shall be spaced not more than 6 ft. center to center.

Tiers of ties shall be not more than 3 ft. apart.

(e) *Fastenings.*—Each successive tier of close face cribbing shall be drift bolted to the one upon which it rests by drift bolts not less than ¾ in. in size and of sufficient length to extend through two tiers and not less than 4 in. into the third tier. Drift bolts shall be staggered and not more than 8 ft. center to center in each tier. All end joints and splices shall be half lapped and drift bolted at the center. Ties shall be drift bolted to face timbers in like manner. See Fig. 3.

Each successive tier of open face cribbing shall be drift bolted together at each tie using one ¾ in. drift bolt at each intersection where no splice occurs or at lap joints and two ¾ in. drift bolts at butt joints. Drift bolts shall be long enough to extend through one tier and at least ¾ of the distance into the next tier. Stagger drift bolts from tier to tier. See Fig. 2.

In treated timber cribbing, the hardware shall be galvanized.

(f) *Filling.*—The filling of the interior of the crib shall follow closely the erection of the successive tiers of units and at no time shall the wall be laid up higher than 3 ft. above the backfilled portion.

Approved fill material of crushed stone or other coarse granular material, rock (12 in. maximum dimension), or a combination of these shall be placed in layers not exceeding 12-in. thickness and tamped or consolidated in a satisfactory manner. Care shall be used in placing rock filling material so as to avoid damaging or dislodging the cribbing members. The puddling method of filling shall not be used. All vegetable matter shall be excluded from the filling material. Clay or material having a large percentage of clay shall not be used as fill.

In open face cribbing a layer of hand placed stone shall be placed in back of the front members of the cribbing to prevent loss of fill material through the openings.

Part 3—Reinforced Concrete Culvert Pipe

The following specifications for reinforced concrete culvert pipe are submitted as information so that they may be considered during the coming year by the Association, after which they will be offered for adoption and publication in the Manual to replace the specifications now appearing on pages 8–90 to 8–90.1 and 8–123 to 8–127, incl.

SPECIFICATIONS FOR REINFORCED CONCRETE CULVERT PIPE

A. MANUFACTURE AND DESIGN

1. Reinforced Concrete Culvert Pipe

Reinforced concrete pipe used in the construction of culverts carrying railroad tracks shall conform to the requirements of ASTM Specifications C 76–41, except that Sections 2, 9, 10, 13, 17, 24 (c), 31 and 34 shall be modified as indicated; Tables I and II shall be deleted; and Table III shall be added.

TABLE III.—DESIGN AND STRENGTH TEST REQUIREMENTS OF REINFORCED CONCRETE PIPE FOR RAILWAY LOADING

Internal Diameter of Pipe Inches	*Concrete 4500 Lb. per Sq. In.*			*Strength Test Requirements Lb. per Linear Ft. of Pipe*	
		Minimum Reinforcement Sq. In. per Linear Ft. of Pipe Barrel		*Three-Edge-Bearing Method*	
	Minimum Shell Thickness Inches	*Circular Reinforcement in Circular Pipe*	*Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe*	*Load to Produce a 0.01 Crack*	*Ultimate Load*
15	2¼	1 line 0.20	----------	3,500	5,500
18	2½	1 " 0.25	----------	4,500	6,500
24	3	1 " 0.37	1 line 0.31	6,000	8,500
30	3½	1 " 0.48	1 " 0.37	7,500	10,500
36	4	2 lines, ea. 0.43	1 " 0.43	9,000	13,000
42	4½	2 " " 0.50	1 " 0.50	10,500	15,000
48	5	2 " " 0.56	1 " 0.56	11,500	17,000
54	5½	2 " " 0.62	1 " 0.62	13,000	19,500
60	6	2 " " 0.68	1 " 0.68	14,500	21,500
66	6½	2 " " 0.74	1 " 0.74	16,000	23,500
72	7	2 " " 0.80	1 " 0.80	17,500	25,500
78	7½	2 " " 0.87	1 " 0.87	19,000	28,000
84	8	2 " " 0.93	1 " 0.93	20,500	30,000
90	8	2 " " 1.05	1 " 1.05	22,000	32,000
96	8½	2 " " 1.11	1 " 1.11	23,500	34,000
102	8½	2 " " 1.25	1 " 1.25	24,500	36,000
108	9	2 " " 1.30	1 " 1.30	26,000	38,000

2. Class

Pipe manufactured to these specifications shall be known as Reinforced Concrete Pipe for Railway Loading.

3. Minimum Designs

The shell thickness and the amount of circumferential reinforcement shall be not less than that prescribed in Table III.

4. Alternate Designs

Manufacturers may submit to the purchaser, for approval, designs other than those in Table III, provided that such pipe shall conform to the same physical tests and inspection requirements prescribed in these specifications for the pipe for which it is substituted. In no alternate design, however, shall the shell thickness be less than that prescribed in Table III.

5. Laps, Welds, and Spacing

If the splices are not welded, the reinforcement shall be lapped not less than 30 diameters for bars, and 40 diameters for cold drawn wire.

If welded, the weld shall be at only one point in the middle of the lap, and the length of the lap shall be not less than 15 diameters for bars and 20 diameters for cold drawn wire. The member at a welded splice shall develop a tensile strength at least 80 percent of the minimum strength required for the reinforcement by the applicable specifications cited in Section 6 of the ASTM Specifications. Longitudinal bars shall be either electrically welded or wired to circumferential bars. Gas welding will not be permitted.

The spacing center to center of adjacent rings of circumferential reinforcement in a cage shall not exceed 4 in. for pipe up to and including 48 in. diameter, nor exceed the shell thickness for larger pipe, and shall in no case exceed 6 in.

6. Strength Requirements

The ultimate loads, as determined by either of the methods described in Sections 25 and 26 of the ASTM Specifications shall be not less than the ultimate load prescribed in Table III. The pipe shall conform in other respects to the provisions of Section 17 of the ASTM Specifications.

7. Apparatus

The provisions of Section 24 of the ASTM Specifications shall be followed except that in paragraph (c) Table III shall be substituted for Tables I and II.

8. Standard Sizes

Pipe of the internal diameters listed in Table III shall be the standard sizes for culvert construction. In eliptical pipe, the inside diameter at the minor axis shall be equal to the diameter of the corresponding size of circular pipe.

9. Marking

The following shall be clearly stenciled on the pipe:

R–C to indicate the class.

The date of manufacture.

The name or trade mark of the manufacturer.

Elliptical pipe with circular reinforcing and circular pipe with elliptical reinforcing shall have the word "Top" or "Bottom" clearly stenciled on the inside of the pipe at the correct place to indicate the proper position when laid.

10. Special Pipe

Pipe having a shell thickness greater than that listed in Table III shall be reinforced to carry a minimum uniform load of 2500 psi. on the projected horizontal diameter (inside diameter plus shell thickness) with a corresponding foundation reaction, without lateral restraint, at allowable working stresses in the concrete and reinforcing steel. The bending moment coefficients are given in case 3 of the Table of Coefficients for Computing Moments and Thrusts in Culvert Pipe, accompanying this specification.

TABLE OF COEFFICIENTS FOR COMPUTING MOMENTS AND THRUSTS IN CULVERT PIPE

LOAD	MOMENT AT CROWN	MOMENT AT BOTTOM	MOM AT END OF HORIZ. DIA	THRUST AT CROWN	THRUST AT BOTTOM	THRUST AT HORIZONT. DIAMETER
(1)	+0.159	+0.159	-0.091	0	0	+0.5
Concentrated Load Top & Bottom.						
(2)	+0.147	+0.075	-0.077	+0.053	-0.053	+0.5
(3)	+0.0625	+0.0625	-0.0625	0	0	+0.5
Uniform Load Top & Bottom.						
(4)	+0.096	+0.153	-0.084	-0.0265	+0.0265	+0.5
(5)	-0.052	-0.073	+0.0625	+0.3125	+0.6875	0
Lateral Pressure without Surcharge.						
(6)	+0.090	+0.090	-0.077	0	0	+0.5
Triangular Load Top & Bottom.						
(7)	+0.084	+0.068	-0.070	+0.0265	-0.0265	+0.5

Moment = C·W·D

Thrust = C·W

W = Total Load on One Half of Pipe; i.e, on left or right half of Case 5, & on upper or lower half of Cases 1, 2, 3, 4, 6 & 7.

D = Diameter of Pipe.

11. Special Loading

Pipe carrying special loading shall be designed by using the bending moment coefficients from the table for the particular loading under consideration. In no case, however, shall the shell thickness be less than that listed in Table III, nor the reinforcement be less than that required by Section 10.

Note. Your committee proposes tc include in these specifications as section B. Placement, the matter now appearing in the Manual on pages 8–123 to 8–127, incl., under the heading, Specifications for the Placement of Concrete Culvert Pipe.

Report on Assignment 4

Design and Construction of Foundations for Masonry Structures

Including Spread Footings, Piling, or Other Special Construction Which Supports the Structure and Its Loads, Collaborating with Committees 1, 6, 7, 15 and 30

M. Nearing (chairman, subcommittee), J. R. Burkey, G. H. Dayett, Roscoe Owen, J. H. Shieber, Jamison Vawter, K. J. Wagoner, E. P. Wright.

The following report on pile foundations is submitted as information with the request that it be reviewed and criticized during the coming year prior to submitting the specifications one year hence for adoption and publication in the Manual, at which time they will replace all material now appearing on pages 8–117 to 8–122, incl.

PILE FOUNDATIONS

A. GENERAL

1. Scope

These specifications cover the investigation, design and construction of pile foundation.

2. Purpose and Necessity

Pile foundations may be used when the bearing power of the soil is insufficient to carry the superimposed loads or where the possibility of scour or other disturbance of the soil may cause a change in the underlying foundation condition.

Depending on subsoil conditions, piles act as columns to carry the supported load to the hard substrata, or to consolidate the soil and transfer the load to less firm substrata by skin friction.

B. DESIGN

1. Loads

The pile foundation shall be designed for that combination of the following forces which produces maximum load.

Primary
- (a) Dead
- (b) Live
- (c) Centrifugal force
- (d) Earth pressure
- (e) Buoyancy

Secondary
- (f) Wind and other lateral forces
- (g) Longitudinal forces

2. Increased Load on Piles

When the pile foundations are designed for both primary and secondary forces, as defined above, the allowable load on the piles may be increased by 25 percent, but the number of piles shall not be less than is required for primary forces alone.

3. Eccentricity of Loads

The maximum pile load under eccentric loads shall not exceed the allowable load.

4. Bending in Piles

When piles are not supported laterally by the material through which they are driven, or when driven in stream beds where scour occurs, the sections of the piles shall be proportioned for the combined direct load and bending produced by the specified loads.

5. Uplift on Piles

When piles are subjected to continuous uplift and sufficient bond exists between the pile and the superimposed structure, the uplift may be considered in the design of the pile foundation.

6. Spacing of Piles

Piles shall be spaced so as to distribute their loads to the supporting material according to Article C. The minimum center to center spacing shall be not less than 2½ times the butt diameter or side, or 2½ times the depth of steel H sections. Where practical, piles should be so spaced as to equalize their loads.

C. ALLOWABLE LOAD ON PILES

1. Test Borings and Soil Analysis

Test borings shall be made at enough locations and to a sufficient depth below the foot of the piles to adequately determine the character of the material through which the piles are to be driven and the characteristics of the materials underlying the points of the piles. The borings and soil analysis together with the function of the piles in service shall determine the type, spacing and length of piles that should be used and whether they will be supported as end bearing or friction bearing piles or a combination of both types.

Sufficient borings should be made to determine the thickness of any material that will develop end bearing and the nature of the overlying strata to determine the extent of the lateral support and its probable consolidation. If the bearing stratum is of doubtful thickness, the bearings should be made below it to determine the capacity of the underlying material to support the loads which it will receive.

Laboratory investigations should be made on boring samples to determine the moisture content, the Atterberg limits and compressive strength from unconfined compression tests of cohesive soils. Unit shear may be assumed as one-half the unconfined compression test value.

2. Allowable Load on End Bearing Piles

The capacity of end bearing piles depends on the structural strength of the piles, crushing strength of the pile points, crushing strength of the materials supporting the piles at the point and the supporting strength of the stratum that affords end bearing. The structural and crushing strength of the pile depends upon the type of pile and shall be in accordance with the values provided by AREA specifications. A pile may be considered end bearing when driven to refusal into or on an end bearing stratum. If the end bearing strength of the stratum is ample, the capacity of a pile in a group is equal to the capacity of a single pile. When end bearing piles penetrate unconsolidated material such as new embankment, above the firm stratum, allowance shall be made in the design load to compensate for the additional load that may be imposed on the pile as the material consolidates above the pile point. The design load where the end bearing stratum is sand, gravel, clay, soft rock or shale shall preferably be determined by loading

of test piles. Where end bearing capacity is not determined by test piles, the allowable load at the tip of the pile shall not exceed the safe bearing value of the material supporting the pile as determined by test borings.

3. Allowable Load on Friction Piles

Where piles are driven in groups, the design load may be determined by the loading of a group of test piles, by a laboratory soil analysis of undisturbed samples of the penetrated and underlying soil or by a combination of both methods. A single row of piles shall not be considered as a group provided the piles are spaced at least 2½ times their nominal diameter.

The loading tests shall be made to failure in accordance with the provisions of Article D, Paragraph 9, Class B Test. The average shearing stress in the soil at failure may be determined on the assumption that the total load is distributed on planes through the perimeter bounding the group and extending downward to the tips of the piles. The results of the test are directly applicable only when the piles of the design group are of the same type and have the same penetration, size and spacing as those of the test group and the probable effect of a variation in any of these items shall be reflected in the design. The ultimate capacity of the test group having thus been determined, the working load per pile can be selected using safety factors depending on the nature of the service load and character of the supported structure. Larger safety factors should be used where the entire load is dead load than are required for loads due to a combination of dead, live, wind and horizontal loads. A great deal more settlement (See Note–1) can be expected in a group of a larger number of piles than in the test group with the same load per pile in each group, and safety factors should be chosen which take this relationship into account.

4. Combination End and Friction Bearing Piles

Where the strength of the end bearing stratum is limited and will not support the pile load as defined for end bearing, piles may be designed for a combination of friction and end bearing by a test of a group in the soil above the end bearing stratum and a test of a group driven into or on the end bearing stratum, combined with a soil analysis of both the friction and end bearing strata. Soil borings and soil analysis shall include also an investigation of the material underlying an end bearing stratum that is limited in depth.

5. Lateral Support

A pile shall be considered fully supported laterally except that portion which is or may be, as a result of scour, in air or water, or which may be in muck, peat, thin mud or fluid material. Where a portion of the pile is not supported laterally as a short column, that portion shall be considered as a long column and proper allowance made in the design.

Note–1. Settlement may be calculated approximately with consolidation computations from the borings and soil analysis of material below a point 2/3 of the pile penetration, by assuming the load on each pile of a group is transferred to this point in the ground and distributed into the soil below this 2/3 point as a foundation load.

D. LOADING TESTS

1. Jetted Piles

Piles which have been jetted shall be driven to the desired penetration and the records taken before the test is made.

2. Damaged Piles

Shattered, broomed or otherwise damaged pile heads shall be cut back to sound material before the test is made.

3. Curing Cast-in-Place Piles

Unless otherwise provided, shells or tubes which in service are to be filled with concrete, shall be filled with concrete with time for adequate curing, before the test is made. High-early-strength cement may be used.

4. Application of Loads

Following completion of driving by not less than 48 hours for tests of Class A, nor 72 hours for those of Class B, the test load shall be applied concentrically as near the ground as practicable, by direct weight or by hydraulic jack pressure that is automatically maintained. If anchor piles or devices are used to provide reaction, the axis of the nearest such pile or device shall be located at least 5 ft. from the loaded pile. The initial and subsequent increments shall be applied gradually. The test load and its application shall be so arranged that readings can be taken by the engineers directly on the pile and a record made of the load and settlement simultaneously at any time.

5. Amount of Load

The piles to be tested shall be loaded to at least twice the proposed working load. The initial load shall not exceed 2/3 and the increments shall not exceed 1/3 of the proposed or anticipated working load.

6. Records

Records shall be made of the load, time and settlement as accurately as practicable immediately before and following a change of load. While noticeable settlement is taking place, readings shall be at 10-min. intervals, or less; otherwise at hourly intervals.

7. Loading Tests

Loading tests may be of two classes:

A—Construction test to gage compliance with plans and specifications.
B—Predesign test, to aid the designer.

Since more time is usually available under Class B, and there is larger opportunity to make use of revealed data, such tests can justify a more extended procedure than those under Class A.

8. Class A Test

In making Class A tests, at least 4 hours shall elapse between the applications of successive increments. When the total load equals twice the proposed working load, it shall be left in place at least 48 hours, the last 24 of which shall be free from settlement. If after deducting rebound following the total release of this load, the net settlement at the top of the pile does not exceed ¼ in., the pile shall be considered adequate to support safely the proposed working load.

9. Class B Tests (Predesign)

In Class B tests, the loading shall be carried to failure of the soil or pile. After reaching the anticipated working load, at least 12 hours shall elapse between the applications of successive increments.

(a) For at least three values of test load (say 100 percent, 166-2/3 percent and 200 percent of the anticipated working load), the load shall be released and remain off at least 6 hours. The previous load shall then be restored and maintained until the gross settlement equals that existing at the time of the previous release, whereupon the succeeding increments shall be added.

(b) As the approach of failure is sensed, the load shall be carefully adjusted in order to obtain gradual settlement, if possible, until failure is complete.

(c) Curves shall be plotted, relating the load, settlement and time for the complete period of the test.

(d) The load value where the load-settlement curve begins to show an accelerated deviation from its previous trend, may be considered the "yield point" for the given soil and pile, and ½ of this value or ½ of the value at which the net settlement is estimated as ¼ in., whichever is the smaller, may be considered a safe working load for this pile, acting singly.

(e) Where Class B tests are intended to govern the design of pile groups, a test shall be made on a group which is typical of the contemplated design, if such a test is feasible. In the absence of such a group test, the capacity of the proposed group should be studied in the light of the shearing value and settlement behavior of the soil as revealed by the test of single piles.

10. Rebound

In determining net settlement of a tested pile, deduction shall be made for the elastic recovery of the pile as indicated by the rebound following the release of the test load.

E. TIMBER PILES

1. Specifications

Timber piles shall conform to the AREA Specifications for Wood Piles.

F. PRECAST CONCRETE PILES

1. Design

Piles of constant cross section shall have a least diameter or lateral dimension of 14 in. for piles up to 35 ft. in length and not less than 16 in. for lengths over 35 ft. and not over 50 ft. Piles over 50 ft. in length shall be of a size and design approved by the engineer. Piles may be pointed or not as the engineer directs.

Piles with a uniform taper shall have a minimum lateral dimension of not less than 8 in. at the tip and an average diameter of not less than 12 in. for lengths not over 40 ft. Piles over 40 ft. shall have a minimum taper of 1 in. in 8 ft. and a lateral dimension at the tip of not less than 10 in.

The reinforcement shall consist of longitudinal bars, supported by lateral reinforcement in the form of hoops or spirals. The longitudinal reinforcement shall be designed for handling stresses and shall normally consist of 8 bars, uniformly spaced, and not less than ½ in. nor more than 1 in. in size. The cross-sectional area of the longitudinal reinforcement shall be not less than 1 percent nor more than 4 percent of the average cross-sectional area of the pile. The lateral reinforcement shall consist of not less than No. 7 steel wire, spaced not more than 8 in. center to center throughout the length

of the pile, except that for not less than 2 ft. at each end the spacing shall not exceed 3 in. center to center. The reinforcement shall be placed with a cover of not less than 1½ in. and greater cover as conditions require. Steel reinforcement shall conform to the requirements of the AREA Specifications for Concrete and Reinforced Concrete.

2. Cut-Off

Precast piles shall be driven to or cut off within 2 in. of the elevation shown on plans, but in all cases the cut-off shall be below any indication of fracture. If piles are cut off or driven below the required elevation they shall be built up to the cut-off line in a manner satisfactory to the engineer.

3. Allowable Stresses

The allowable load per pile shall be determined as specified in Articles C and D but the unit stresses shall not exceed the allowable stresses specified in the AREA Specifications for Concrete and Reinforced Concrete.

G. PRECAST CONCRETE PILES—MANUFACTURE

1. General

The workmanship, material and proportioning shall conform to the requirements as specified in the AREA Specifications for Concrete and Reinforced Concrete.

2. Aggregates

The maximum size of the coarse aggregate shall be not more than 1 in. nor more than ¾ of the minimum clear spacing of reinforcement or the minimum distance from reinforcement to forms.

3. Class of Concrete

The concrete shall be Class 3700, using not more than 5½ gal. of water per sack of cement.

4. Workability and Placement

The mixture shall be of workable consistency dependent on the method of placement to insure complete embedment of reinforcement and prevent honeycombing. Vibrating equipment shall preferably be used and it shall be of a type approved by the engineer.

5. Curing

Moist curing shall be begun as soon as possible after completion of placement of the concrete and comply with "curing" specifications. The surface of the concrete shall be kept continually wet during the curing period. Curing shall be continued until the concrete has attained 2500 psi., as shown by test cylinders under like curing or as specified by the engineer. Substitutes for moist curing will be accepted only on specific permission of the engineer.

6. Marking

Each pile shall be stamped or marked with the date of its manufacture. Lifting points indicated on plans shall be plainly marked.

7. Handling

Piles may be handled and driven only when the concrete has attained a compressive strength of 3700 psi. unless special provision is made for handling that will reduce the

stresses in proportion to the strength of the concrete as shown by test cylinders cured under external conditions like those obtaining for the concrete in the piles. Piles shall be handled carefully, avoiding dropping or severe jarring while in a horizontal position.

H. CAST-IN-PLACE CONCRETE PILES

1. Types

Cast-in-place piles shall be cast in previously driven metal shells which shall remain permanently in place. They may be tapered or cylindrical or a combination of tapered and cylindrical shapes. Where steel cylindrical shells are used, 5/16 in. thick or more, they shall be classed as steel pipe piles and shall be as specified under Article J.

2. Tapered Piles

Tapered piles shall be not less than 8 in. in diameter at the tip and shall be uniformly tapered at the rate of not less than 1 in. in 8 ft., with a minimum butt diameter of 12 in.

3. Cylindrical Piles

Cylindrical piles shall be of a size and design approved by the engineer but shall in no case be less than 12 in. in diameter.

4. Metal Casings

The metal casings or shells shall be formed of basic open-hearth steel. The metal of shells driven with a mandrel shall have a thickness of not less than No. 18 B.W.G. The metal of shells driven directly shall have a thickness of not less than No. 7 B.W.G. except where fluted shells are used the minimum thickness may be No. 9 B.W.G. When driving without a mandrel the tips shall have a steel driving point welded to the shell. The shells shall be in one integral piece or adequately spliced and they shall be of sufficient thickness to withstand driving without failure.

5. Placing Concrete

Shells shall be inspected and approved by the engineer immediately before any concrete is placed. They must be clean and free of any water or foreign matter. They must be undistorted and of the specified dimensions. The concrete shall be not inferior to Class 2500 and the placing shall be continuous from tip to cut-off elevation, and shall be carried on in such a manner as to avoid segregation.

Reinforcement shall not be used unless especially specified.

No cast-in-place pile shall be filled with concrete until all adjacent piles within a radius of 4½ times the average pile diameter, or not less than 5 ft., have been driven to the required resistance.

After a shell has been filled with concrete, no shell or pile shall be driven within 15 ft. thereof until at least 4 days have elapsed.

6. Allowable Stresses

The allowable load per pile shall be determined as specified in Articles C and D but the unit stresses shall not exceed the following:

Friction piles and end bearing piles passing through firm soils—0.25 of the compressive unit strength of the concrete used.

End bearing piles passing through soil having poor lateral resistance and with a slenderness ratio equal to or less than 10—0.20 of the compressive unit strength of the concrete used.

End bearing piles passing through soil having poor lateral resistance and having slenderness ratios greater than 10 should be designed as long columns and reinforced.

Where the encasement is ⅛ in. or more in thickness and of suitable shape it may be considered as being stressed 12,000 psi., provided that in computing the effective area of the steel, the outer 1/16 in. of thickness of surface exposed to the soil shall be deducted.

7. Protection Against Corrosion

(To apply if the steel encasement is used in computing the strength of the pile)

Piles which will be exposed shall be protected from corrosion by means of concrete encasement extending at least 1 ft. above the ground surface or normal water line and 3 ft. below the ground surface or low water line. The minimum concrete cover shall be 3 in.

If the strength of the steel is applied in computing the strength of the pile, the pile shall not be used through active rust inducing material or where electrolysis may occur without adequate provision for the protection of such pile.

J. PIPE PILES (STEEL PIPES FILLED WITH CONCRETE)

1. Size

Pipe shall have an inside diameter of 10 in. or more and a thickness of not less than ⅜ in., except that a thickness of 5/16 in. may be used for 10 in. and 12 in. pipe.

2. Splicing

Splices shall be of an approved design, consisting preferably of butt welded joints. Where conditions permit, sleeves may be used. When sleeves are used the ends of the pipe shall be faced perpendicular to the axis. Sleeves should be a tight driving fit on or in the pipe and should extend a distance equal to the diameter of the pipe above and below the splice. Means shall be provided for the prevention of movement of the sleeve during driving of the pile.

3. Capping

The tops of piles shall project not less than 12 in. into the foundation concrete.

4. Placing Concrete

The inside of pipes must be cleaned of any foreign matter before concrete is placed. The concrete shall be not inferior to Class 2500 and the placing shall be continuous from the tip to the cut-off elevation, and shall be carried on in such a manner as to avoid segregation. No interior reinforcement shall be used.

No pipe pile shall be filled with concrete until all adjacent piles within a radius of 4½ times the average pile diameter, or less than 5 ft., have been driven to the required resistance.

After a pipe has been filled with concrete, no pipe or pile shall be driven within 15 ft. thereof until at least 4 days have elapsed.

5. Protection Against Corrosion

Piles which will be exposed shall be protected from corrosion by means of concrete encasement extending at least 1 ft. above the ground surface or normal water line and 3 ft. below the ground surface or low water line. The minimum concrete cover shall be 3 in.

Pipe piles shall not be used through active rust inducing material or where electrolysis may occur, without adequate provision for the protection of such piles.

6. Allowable Stresses

The allowable load per pile shall be determined as specified in Articles C and D but the unit stresses shall not exceed the following:

Concrete: 0.25 of the compressive unit strength of the concrete used.

Steel: Using fully welded joints—12,000 psi., provided that in computing the effective area of the steel, the outer 1/16 in. of thickness of surfaces exposed to the soil shall be deducted and provided that the total load carried by the steel shall not exceed ½ the total load on the pile.

Using unwelded sleeves—9000 psi., provided that in computing the effective area of the steel, the outer 1/16 in. of thickness of surface exposed to the soil shall be deducted and provided that the total load carried by the steel shall not exceed ½ the total load on the pile.

K. H-SECTION STEEL PILES

1. Material

All steel used for piles shall conform to the AREA Specifications for Structural Steel.

2. Size

The minimum depth of section shall be 8 in. The minimum thickness of metal in the web or flange shall be ⅜ in. The flange width shall be not less than 85 percent of the depth of the section.

3. Splicing

Full length piles shall be used where practicable, but if splices cannot be avoided, an approved method of splicing shall be used. Piles shall not be spliced except by permission of the engineer.

4. Capping

Where steel bearing plates are required they shall be suitably fastened to the top of the piles so as to avoid displacement and to provide as practically as possible an even bearing on the pile with at least 50 percent of the pile top in contact with the bearing cap. The bearing concrete shall not exceed 1000 psi. The tops of piles shall project not less than 12 in. into the concrete.

Piles which extend several feet into a concrete footing may be bonded to the concrete by means of a mat of reinforcing bars running through holes in the piles.

5. Protection Against Corrosion

Piles which will be exposed shall be protected from corrosion by means of concrete encasement extending at least 1 ft. above the ground surface or normal water line and 3 ft. below the ground surface or low water line. The minimum concrete cover shall be 3 in.

Structural steel piles shall not be used through active rust inducing material, or where electrolysis may occur, without adequate provision for the protection of such piles.

6. Allowable Stresses

The allowable load per pile shall be determined as specified in Articles C and D, but the unit stresses on H-section piles shall not exceed 12,000 psi., provided that in computing the effective area of the steel, the outer 1/16 in. of thickness of surfaces exposed to the soil shall be deducted. Due allowance shall be made for any bending or column action.

L. DRIVING PILES

1. Equipment

Piles shall be driven with the heaviest hammer that, in the judgment of the engineer, can be used to secure maximum penetration without damage to the pile.

For driving precast concrete piles a hammer shall be used which will develop energy equivalent to 1750 ft. lb. per ton of pile weight.

The boiler used to supply steam for the operation of a steam hammer shall have a capacity sufficient to maintain full rated steam pressure at least equal to that recommended by the manufacturer of the hammer being used, throughout the driving period of any pile.

2. Cushion Cap

Timber and precast concrete piles shall be protected with an approved cushion cap while being driven.

3. Splicing

Driving shall be continued until the plan cut-off is reached or until the rate of penetration specified is obtained. If the proper resistance to driving is not attained at the plan cut-off, the driving shall be continued and the additional length of pile required shall be supplied by splicing in such a way as to develop the full strength of the section of the pile.

4. Jetting

Piles may be jetted, where conditions warrant, but they shall be driven to final penetration, or driven to refusal. In jetting piles, equipment satisfactory to the engineer for an ample supply of water at adequate pressure shall be provided before jetting is begun.

5. Improperly Driven and Damaged Piles

Piles shall be driven in correct location and with a variation of not more than ¼ in. per ft. from the vertical, or from the batter line when batter piles are required. Any pile so out of line or plumb as to impair its usefulness shall be pulled and redriven or an additional pile driven, as required by the engineer. Any pile so injured in driving or handling as to impair its structural capacity as a pile under the conditions of use shall be replaced by a new pile, or the injured part shall be replaced by splicing or other remedial measures—all as directed by the engineer.

6. Redriving of Displaced Piles

End bearing piles shall be carefully checked during the driving of adjacent piles and, if any uplift occurs, they shall be redriven to refusal or the desired penetration.

7. Interrupted Driving

When driving is interrupted or the rate of blows retarded for any reason, a careful record shall be kept of the extent of the delay or retardation. Any decrease in the penetration per blow immediately following such instances, shall be disregarded in estimating by formula the bearing capacity of the pile.

Report on Assignment 6

Methods of Designing, Constructing, and Maintaining Tunnels, Collaborating with Committees 1, 5, 28 and 29

C. B. Porter (chairman, subcommittee), G. F. Eberly, W. P. Geiser, G. A. McRoberts, R. V. Proctor, E. T. Rucker, D. H. Shoemaker, Neil Van Eenam.

Your committee presents as information the following tentative specifications for lining railway tunnels with timber. This specification will be a new section in Chapter 8, and, accordingly, critical review is invited so that it may be constructively amended before being offered a year hence for adoption and publication in the Manual.

D. LINING RAILWAY TUNNELS WITH TIMBER

1. Scope

These specifications cover the lining of new tunnels through ordinary formations which involve no special features.

2. Timber—Untreated

The timber for untreated lining shall be white oak, Douglas fir, or other approved wood, of stress grades specified in AREA Specifications for Structural Timber.

3. Timber—Treated

The timber for treated lining shall be southern pine, Douglas fir, or other approved wood, of stress grades specified in AREA Specifications for Structural Timber.

4. Timber—Treatment

The preservative and treatment shall be in accordance with current specifications in the chapter on Wood Preservation of the AREA Manual, with chemicals, retentions and fire retardant requirements as shown in Navy Department specifications 51–C–38 and 51–C–40. Methods of test for combustible properties of treated wood shall be in accordance with ASTM specifications, designations E 69–46T and E 160–46.

So far as practicable, timber shall be framed and bored before treatment and field work of this character shall be limited to a minimum. Timber which must be cut or bored after treatment shall have the surface so exposed painted thoroughly with two coats of the preservative used in the original treatment. Holes shall be filled with the preservative as specified by the engineer.

5. Interior Dimensions

The interior dimensions of the clear space provided for single and double track tunnels shall not at any point be less than tunnel clearances recommended by the AREA.

On curved track the clearances shall be increased to allow for the overhang and the tilting of a car 85 ft. long, 60 ft. between centers of trucks, and 14 ft. high. The superelevation of the outer rail shall be in accordance with the recommended practice of the AREA.

To provide for drainage. a minimum side clearance of 9 ft. 0 in. shall be used in tunnels likely to be wet.

6. Set Spacing

Spacing of timber sets, posts and arch segments, shall be as specified by the engineer, but shall not exceed 6 ft. 0 in. center to center.

7. Preparing Foundation

To provide an even bearing for mud blocks, the tunnel floor under the sills shall be brought to a true grade 8 in. below the bottom of the sills by the use of grouted stone packing or concrete, as directed by the engineer.

8. Mud Blocks

Mud blocks of timber or precast concrete 8 in. high, not less than 12 in. square, shall be placed under sills at each post location.

9. Sills

Sills shall be not less than 12 in. by 12 in. and of such lengths as to extend continuously under at least 3 posts, if conditions permit. Sills shall be spliced horizontally at the ends to each adjacent sill. Splices shall be 6 in. deep by 12 in. long and securely fastened with bolts as specified by the engineer. Mud blocks shall be fastened to sills as specified by the engineer.

10. Posts

Posts shall be not less than 12 in. by 12 in., cut square at ends and securely fastened to sill and wall plate as specified by the engineer.

11. Wall Plates

Wall plates shall be framed from timber not less than 12 in. by 12 in. and of such length as to extend continuously over at least 3 posts, if conditions permit. When untreated timber is used, wall plates may be dapped in the field to receive the bottom of the hip segment with a firm, even bearing. When treated timber is used, top of wall plates shall be preframed for the entire length to the same mitre as the bottom of the hip segment to permit variable spacing of segments, or dapped for a fixed spacing, prior to treatment. Wall plates shall be spliced horizontally at the ends to each adjacent wall plate. Splices shall be 6 in. deep by 12 in. long, securely fastened with bolts, as specified by the engineer.

12. Segments

Segments shall be not less than 12 in. by 12 in. with mitre joint at ends cut accurately to plan dimensions. Ends of segments shall be fastened as specified by the engineer.

13. Spacers

Where timbering is required within 50 ft. of the face, spacers shall be temporarily installed for a minimum distance of 100 ft. back from the last post erected.

Spacers shall be not less than 2 in. thick by 12 in. wide and shall be used between posts on top of the sills and under the wall plates. Spacers shall be used between segments on top of the wall plate unless the wall plate is dapped for a fixed spacing of hip segments.

14. Joggles

Joggles shall be not less than 4 in. by 8 in. Ends of joggles shall be dapped horizontally 4 in. deep by 6 in. long. A joggle shall be placed at each joint between segments.

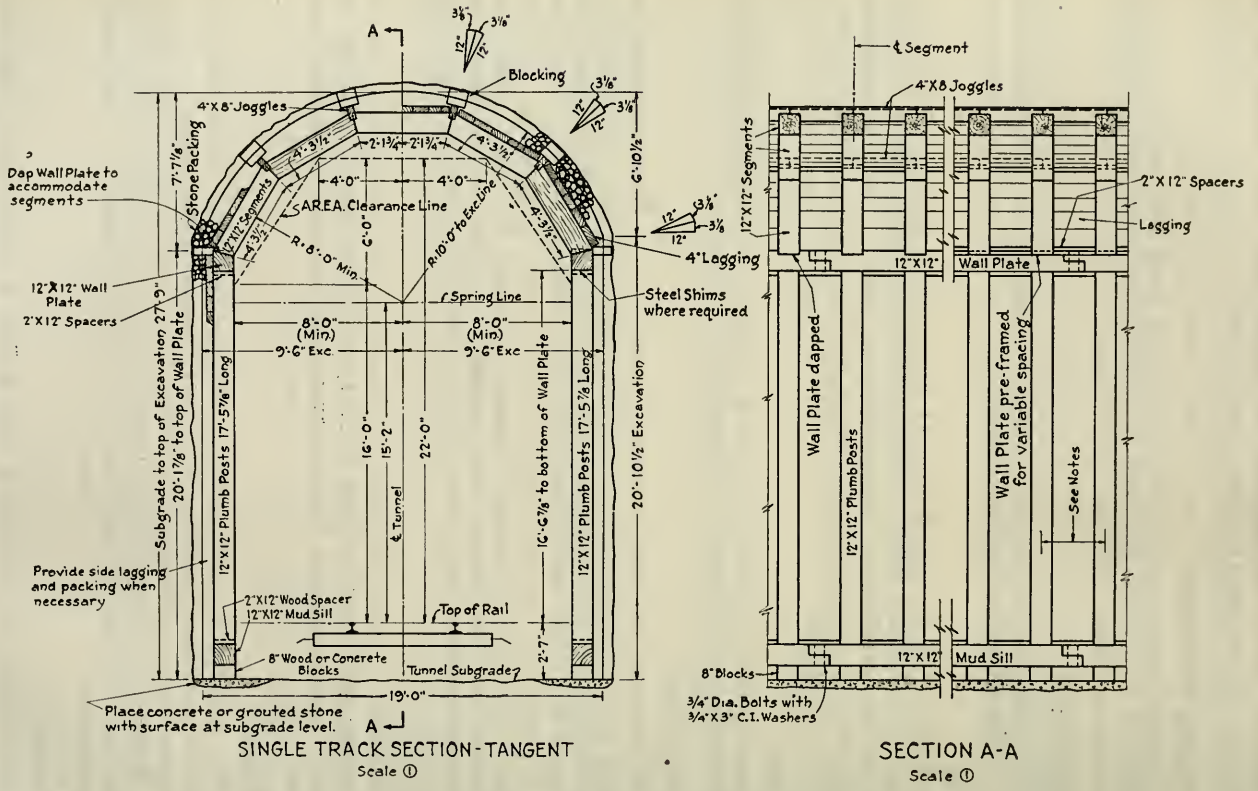
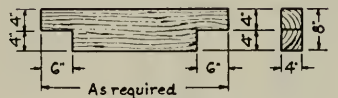


Fig. 1.—Details of Timber Lining for Tunnel.



TYPICAL JOGGLE
Scale ②

Spacers

NOTES

Blocking is to be used at all segment joints.

Spacing of Plumb Posts shall be specified by the Engineer but shall not exceed 6'-0".

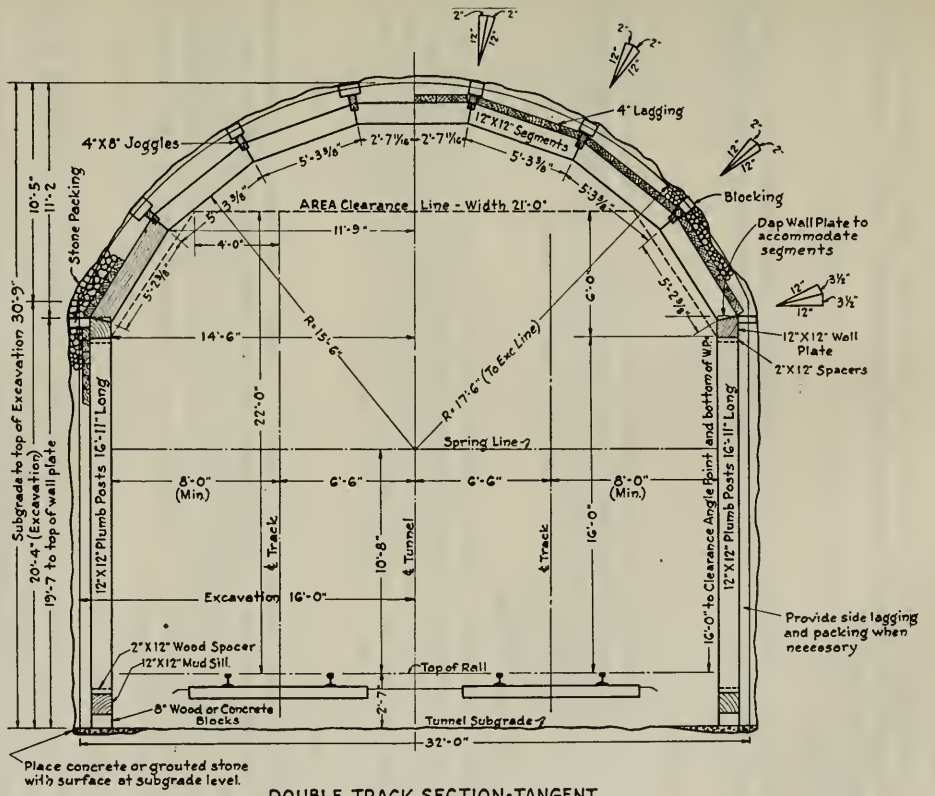
On double track where centers are more than 13 feet, increase distance between sidewalls accordingly. On curved track the clearances shall be increased to allow for the overhang and the tilting of a car 85 feet long, 60 feet between centers of trucks and 14 feet high. The superelevation of the outer rail shall be in accordance with the recommended practice of the AREA.

Provide additional width or make other provision for drainage as conditions require.

SCALE

① 0 2 4 8 Feet

② 0 12 24 32 Inches



DOUBLE TRACK SECTION-TANGENT
Scale ①

Fig. 2.—Details of Timber Lining for Tunnel.

15. Lagging

Lagging shall be not less than 4 in. in thickness and shall be placed on top of segments from wall plate to wall plate. Side lagging shall be used as required in the opinion of the engineer.

16. Blocking

Immediately upon erection the wall plates and all segment joints shall be securely blocked to firm ground. The location of sill, post, and other blocking, shall be determined by the engineer.

17. Packing

All cavities behind lagging shall be packed with timber, or stone, firmly rammed into place, or pea gravel pneumatically placed, as specified by the engineer. Where side packing is not required, arch packing shall be supported at wall plate elevation, as directed by the engineer. Soft stone shall not be used for packing.

18. Full-Section Method

When the full-section method is used for removal of tunnel excavation, the foundation shall be prepared as outlined in Paragraph 203. Mud blocks shall be placed in proper position followed consecutively by the sills, posts, wall plates, segments, joggles, wall plate and segment blocking, lagging and packing, so far as practicable. Other blocking shall be placed as directed by the engineer.

19. Heading and Bench Method

Where the heading and bench method is used for the removal of the tunnel excavation, the wall plates shall be placed first and firmly blocked, followed by the segments, joggles, segment blocking, lagging and roof packing, so far as practicable. Mud blocks, sills and posts, shall be erected upon proper foundation as the removal of the bench excavation advances. Side lagging and packing, if required, shall be placed as directed by the engineer.

20. Allowance for Settlement

The horizontal distance from the center line of the tunnel to the inside edge of the wall plates shall be reduced at least 1 in. to allow for settlement.

When the heading and bench method is used for the removal of the tunnel excavation, the wall plates shall be set slightly above final elevation to allow for settlement, as directed by the engineer. If wall plates do not settle to final elevation upon removal of the bench excavation, the difference in elevation shall be taken up by the use of steel plate shims of proper thickness placed on top of the posts under wall plate.

21. General Arrangement

The general arrangement of timber lining is shown by Figs. 1 and 2.

Report of Committee 7—Wood Bridges and Trestles

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Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects.

1. Revision of Manual.

   No report.

2. Simplification of grading rules and classification of timber for railway uses, collaborating with other organizations interested.

   No report.

3. Specifications for design of wood bridges and trestles.

   No report.

4. Improved design of timber trestles.

   No report.

5. Specifications for inspection of timber trestle railway bridges.

   No report.

6. Methods of fireproofing wood bridges and trestles including fire-retardant-paints, collaborating with Committee 17.

   No report.

7. Design of creosoted timber pile piers for long spans.

   Final report, presented for approval and publication in the Manual ..... page 272

The Committee on Wood Bridges and Trestles,
S. F. Grear, *Chairman.*

AREA Bulletin 471, January 1948.

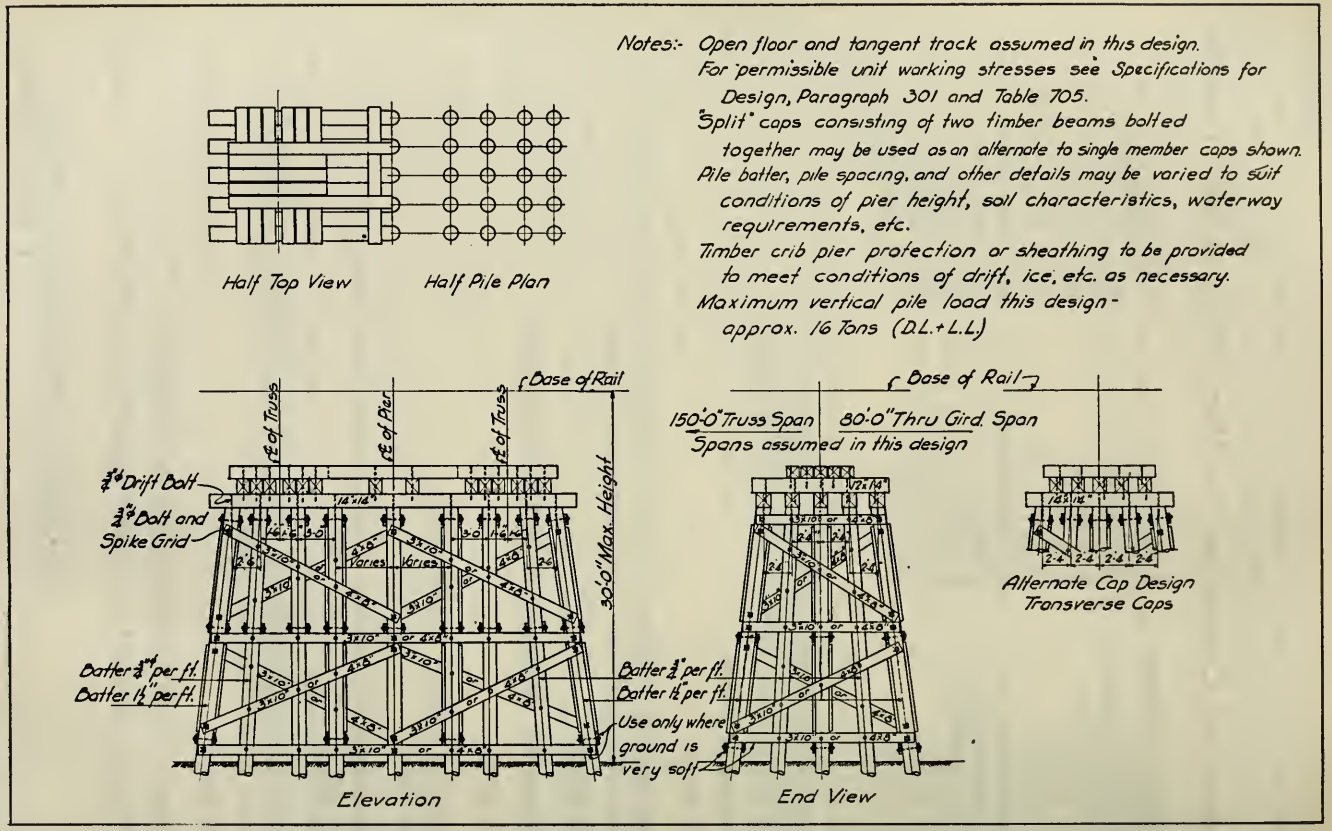

Notes:- Open floor and tangent track assumed in this design.
For permissible unit working stresses see Specifications for Design, Paragraph 301 and Table 705.
"Split" caps consisting of two timber beams bolted together may be used as an alternate to single member caps shown.
Pile batter, pile spacing, and other details may be varied to suit conditions of pier height, soil characteristics, waterway requirements, etc.
Timber crib pier protection or sheathing to be provided to meet conditions of drift, ice, etc. as necessary.
Maximum vertical pile load this design - approx. 16 Tons (D.L.+L.L.)
Half Top View
Half Pile Plan
℄ of Truss
℄ of Pier
℄ of Truss
Base of Rail
30'0" Max. Height
¾"ϕ Drift Bolt
¾"ϕ Bolt and Spike Grid
Batter ½" per ft.
Batter 1½" per ft.
Use only where ground is very soft
Elevation
Base of Rail
150'0" Truss Span
80'0" Thru Gird. Span
Spans assumed in this design
Batter ½" per ft.
Batter 1½" per ft.
End View
Alternate Cap Design
Transverse Caps

Fig. 1.—Recommended Practice for Creosoted Timber Pile Piers for Long Spans, E–60 Loading. Pier for 150-ft. and 80-ft. Spans.

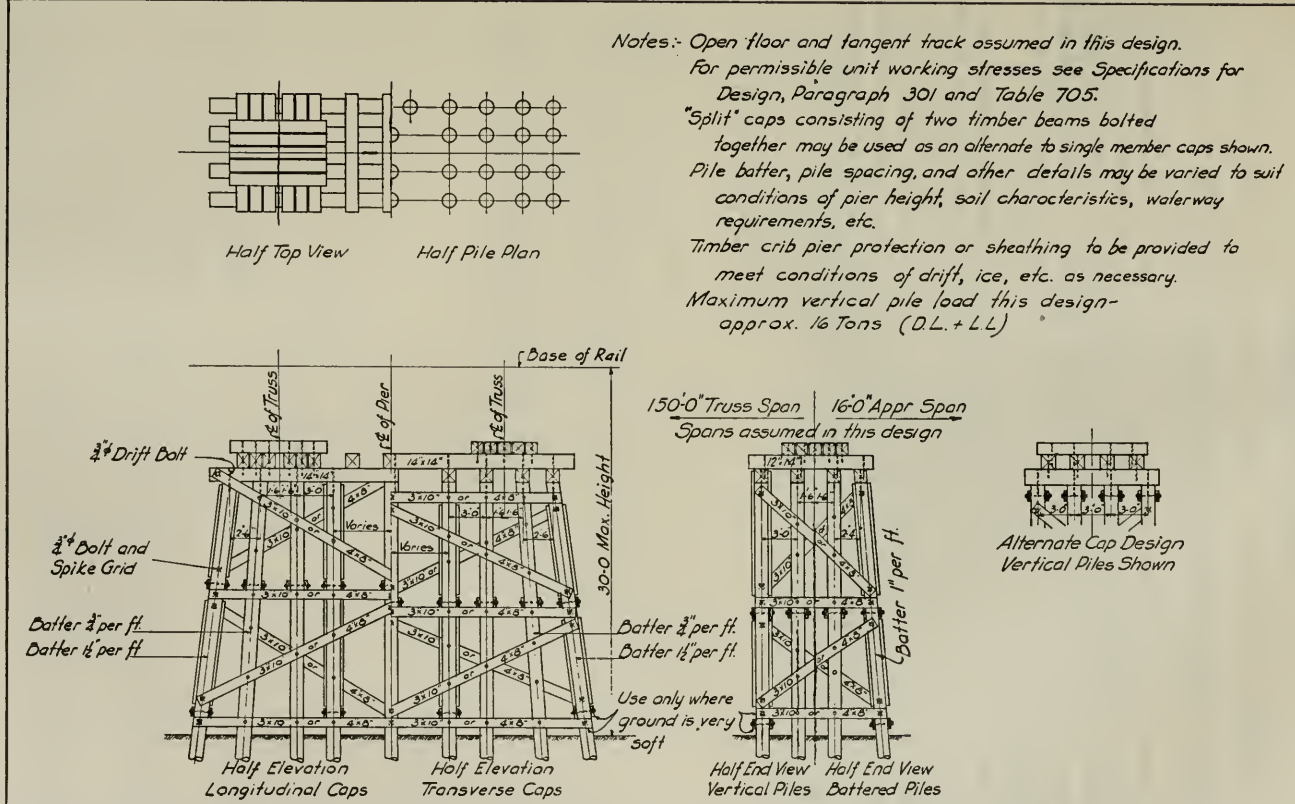

Notes:- Open floor and tangent track assumed in this design.
For permissible unit working stresses see Specifications for Design, Paragraph 301 and Table 705.
"Split" caps consisting of two timber beams bolted together may be used as an alternate to single member caps shown.
Pile batter, pile spacing, and other details may be varied to suit conditions of pier height, soil characteristics, waterway requirements, etc.
Timber crib pier protection or sheathing to be provided to meet conditions of drift, ice, etc. as necessary.
Maximum vertical pile load this design- approx. 16 Tons (D.L.+L.L)
Half Top View
Half Pile Plan
Base of Rail
℄ of Truss
℄ of Pier
℄ of Truss
30-0 Max. Height
¾" Drift Bolt
¾" Bolt and Spike Grid
Batter ¾" per ft.
Batter 1½" per ft.
Varies
Use only where ground is very soft
Half Elevation Longitudinal Caps
Half Elevation Transverse Caps
150'0" Truss Span
16'0" Appr Span
Spans assumed in this design
Batter 1" per ft.
Half End View Vertical Piles
Half End View Battered Piles
Alternate Cap Design Vertical Piles Shown

Fig. 2.—Recommended Practice for Creosoted Timber Pile Piers for Long Spans, E–60 Loading. Pier for 150-ft. Span and Trestle Approach.

Report on Assignment 7

Design of Creosoted Timber Pile Piers for Long Spans

C. V. Lund (chairman, subcommittee), Nelson Handsaker, W. D. Keeney, H. T. Livingston, J. M. Montz, W. C. Schakel, F. E. Schneider, F. W. Small, A. A. Visintainer.

A report on this assignment was presented as information in the Proceedings, Vol. 47, 1946, pages 222–224, incl. The assignment is treated by the development of two plans to illustrate recommended practice in the design and framing of a pier for an assumed truss span 150 ft. long, having either a girder span approach or a pile trestle approach. The plans previously presented have been critically reviewed and revised, and are now submitted for adoption and publication in the Manual as recommended practice.

There are, of course, variations in the details of framing among the railroads, but the essential features of design and arrangement appear to be quite uniform. Suitable notes have been made part of the plans to allow for rather wide variations from the construction shown in meeting local conditions or individual practice. Details of longitudinal and transverse caps are shown as alternates; reference is made in the notes to the use of "split" caps as alternate construction to single member caps. Preservative treatment of piling and timber in accordance with AREA specifications is presumed.

Report of Committee 28—Clearances

J. E. South, *Chairman,*
J. E. Armstrong
C. O. Bird
E. S. Birkenwald
A. B. Chapman
W. T. Davis
J. E. Fanning
C. D. Horton
E. R. Logie
R. R. Manion
R. W. Mauer
R. C. Nissen
A. R. Harris, *Vice-Chairman,*
W. E. Quinn
J. H. Shieber
A. M. Weston

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including recommended revisions below.

2. Clearances as affected by girders projecting above top of track rails, structures, third rail, signal and train control equipment, collaborating with Signal and Electrical Sections, Engineering Division, and with Mechanical and Operating-Transportation Divisions, AAR.

   No report.

3. Provide clearance diagrams for recommended practice, collaborating with committees concerned.

   Progress report, embracing revision and reapproval of Clearance Diagrams for Platforms, submitted for approval ..... page 275

4. Compilation of the railroad clearance requirements of the various states.

   Progress report, presented as information ..... page 275

The Committee on Clearances,
J. E. South, *Chairman.*

Report on Assignment 1

Revision of Manual

J. E. Fanning (chairman, subcommittee), J. E. Armstrong, E. R. Logie, R. W. Mauer, W. E. Quinn, A. M. Weston.

Your committee recommends the following revisions:

1. Under Table of Contents—change the word "Clearances" to read "Special Notes."
2. Page 28–1—change second "Clearances" to read "Special Notes."

Item 1.—Change sentence reading, "The clearances on straight track shall be not less than those shown," to read, "The clearances on tangent track shall be not less than those shown."

AREA Bulletin 471, January 1948.

CLEARANCE DIAGRAMS FOR PLATFORMS

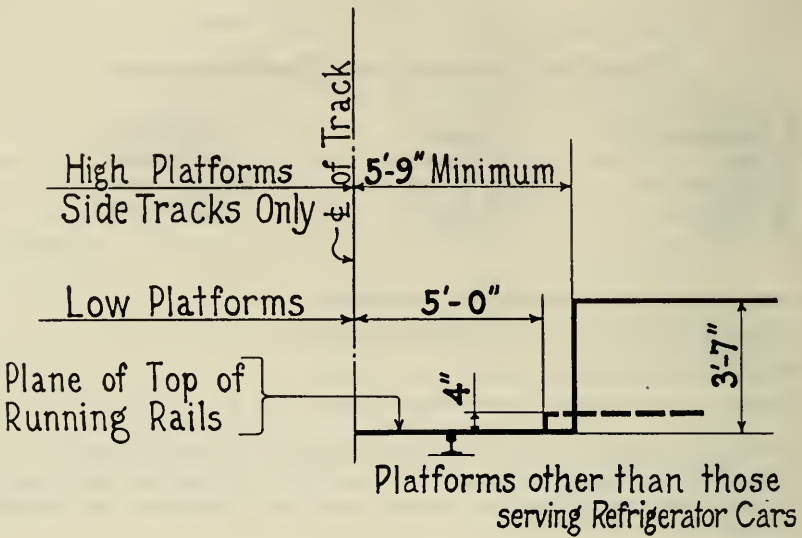


Fig. 7.

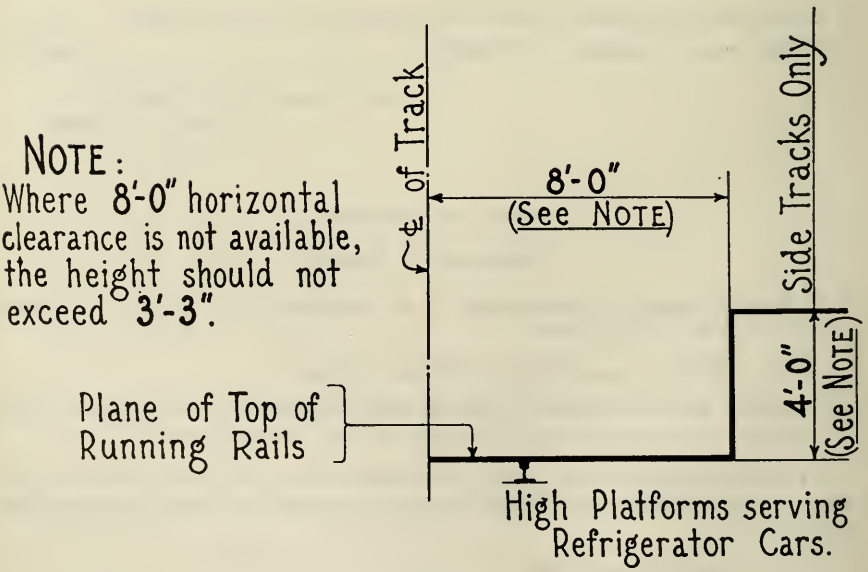


Fig. 8.

LEGAL REQUIREMENTS-CLEARANCES

| STATE | ADOPTED CLEARANCE RULES OR REGULATIONS | | MILES OF TRACK AS OF DECEMBER 31, 1942 | PERCENT OF TOTAL MILEAGE IN U.S. | CLEARANCES BASED ON MAXIMUM CAR SIZES | | SPACING BETWEEN TRACKS | | | | | | | | | | | | | | | | | | OVERHEAD CLEARANCES | | | | | | | | | | | | | | | | | | SIDE CLEARANCES | | | | | | | | | | | | | | | | | |

Item 5.—Change sentence reading, "Legal requirements to govern when in excess of dimensions shown," to read, "Legal requirements to govern when in conflict with dimensions shown."

Report on Assignment 3

Provide Clearance Diagrams for Recommended Practice, Collaborating with Committees Concerned

A. R. Harris (chairman, subcommittee), J. E. Armstrong, C. O. Bird, E. S. Birkenwald, J. E. Fanning, R. R. Manion, J. H. Shieber

Your committee has revised Fig. 7, Clearance Diagrams for Platforms, page 28-8, and submits a revision of Fig. 7 for approval and Fig. 8 for reapproval.

Report on Assignment 4

Compilation of the Railroad Clearance Requirements of the Various States

C. D. Horton (chairman, subcommittee), A. B. Chapman, W. T. Davis, R. R. Manion, R. W. Mauer, R. C. Nissen, A. M. Weston.

Your committee submits as information a tabulation of the clearance requirements of the various states.

Report of Committee 30—Impact and Bridge Stresses

A. B. Chapman, *Chairman,*
E. S. Birkenwald
F. H. Cramer
J. A. Erskine
S. F. Grear
A. R. Harris
Meyer Hirschthal
C. S. Johnson
M. B. Lagaard
A. N. Laird
N. J. Law
H. T. Livingston
C. T. G. Looney
R. W. Mabe
N. M. Newmark
M. J. Plumb
W. E. Robey
J. P. Walton, *Vice-Chairman,*
G. E. Robinson
C. H. Sandberg
J. H. Shieber
C. E. Sloan
R. L. Stevens
F. E. Turneaure
W. M. Wilson
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Tests of viaduct columns, collaborating with Committee 15.

   Progress report, presented as information ..... page 277

2. Tests of steel girder spans with open and ballasted deck, including spans with precast concrete decks and poured-in-place concrete decks; also tests on ballasted decks with timber floor; particular attention to be given to the damping due to the type of deck and the track ballast.

   Progress report, presented as information ..... page 277

3. Tests of dynamic shear in steel girder and truss spans.

   Progress report, presented as information ..... page 277

4. Tests of impact and bending stresses in columns and hangers of steel spans.

   Progress report, presented as information ..... page 278

5. Tests of rigid frame structures of steel and concrete.

   No report.

6. Analysis of additional data from impact tests.

   No report.

7. Determination of damping factors of steel spans and the variation in amount of damping with change in loading, by means of tests with an oscillator and model tests.

   Final report, presented as information ..... page 278

8. Determination of stresses and impacts in timber stringer bridges, collaborating with Committee 7.

   Progress report, presented as information ..... page 278

9. Tests of steel truss spans with open and ballasted deck, particular attention to be given to the damping due to the type of deck and the track ballast.

   Progress report, presented as information ..... page 278

AREA Bulletin 471, January 1948.

10. Distribution of live load in transverse floors and longitudinal stringers.

Progress report, presented as information ..... page 279

11. Stresses in lateral bracing of bridges.

Progress report, presented as information ..... page 284

The Committee on Impact and Bridge Stresses,
A. B. Chapman, *Chairman.*

Report on Assignment 1

Tests of Viaduct Columns

Collaborating with Committee 15

During the past season, the strains were measured in the columns and bracing of three viaducts supporting short truss and girder spans. The longest columns were about 90 ft. and strain gage readings were taken at the top, center and bottom of the columns. Readings were secured under steam locomotives at speeds ranging from 5 mph. to 40 mph. The analysis of these data indicates that, while the impact effects are small, the bending stresses in the columns are quite high. The data indicate that several of the columns are bearing on one edge or on one corner.

Report on Assignment 2

Tests of Steel Girder Spans with Open and Ballasted Deck

During the past season tests have been made on several more girder spans as part of this assignment. The analysis of the data secured on most of the girder spans tested so far has been completed and the six highest recorded impacts secured in these girder spans can be found in the diagram presented this year in the annual report of Committee 15—Iron and Steel Structures. The six highest impacts in the girder spans will be found in the current report of the Committee on Iron and Steel Structures—the impacts under rolling equipment with hammer blow in Fig. 1, page 209 and the impacts under rolling equipment without hammer blow in Fig. 3, page 211.

Report on Assignment 3

Tests of Dynamic Shear in Steel Girder and Truss Spans

The dynamic shear in the girder web plates have been measured in connection with the tests made under Assignment 2. Progress is reported in assembling data on this subject.

Report on Assignment 4

Tests of Impact and Bending Stresses in Columns and Hangers of Steel Spans

The research staff of the AAR collaborated with Purdue University during the past season in measuring the static and live load stresses in the floor-beam hangers of a 127-ft. through truss span on the Illinois Central Railroad close to Galena, Ill. Progress is reported in assembling and analysis of data on this subject.

Report on Assignment 7

Determination of Damping Factors of Steel Spans and the Variation in Amount of Damping with Change in Loading, by Means of Tests with an Oscillator and Model Tests

A report of the investigation of bridge impacts with a mechanical oscillator was presented in AREA Bulletin 467, June–July 1947. It is the conclusion of the committee that this method is not satisfactory in determining the amount of impact in railroad bridges, and the report published in this bulletin is the final report of the committee on this subject.

Report on Assignment 8

Determination of Stresses and Impacts in Timber Stringer Bridges

Collaborating with Committee 7

Tests were made during 1947 on the stringers of an open deck trestle. The static and dynamic stresses were measured in the top and bottom of the three-ply chord stringers under both rails at the center of the span and in the top of the continuous stringers over the cap.

Tests were also made during 1947 on the stringers of a ballasted deck trestle. The static and dynamic stresses were measured in the bottom of the stringers at the center of the span and in the top of the continuous stringers over the cap.

The stresses in the deck timbers of several open and ballasted girder spans have been measured during the tests of girder spans for Assignment 2. The simultaneous and maximum stresses were measured in 12 consecutive ties under slowly moving locomotives to determine the distribution of axle loads to the timbers. Progress is being made in the analysis of the assembled data.

Report on Assignment 9

Tests of Steel Truss Spans with Open and Ballasted Deck

A report of the investigation of impacts and bending stresses in two truss spans on the Toledo Terminal Railroad was presented in AREA Bulletin 468, September–October 1947.

The stresses and impacts were measured in the individual web and chord members of a 142-ft. deck span and a 250-ft. through draw span and these data were presented as information.

Report on Assignment 10

Distribution of Live Load in Transverse Floors and Longitudinal Stringers

Digest

This report describes the results of tests made on the transverse floorbeams of a 100-ft. ballasted deck through girder span of modern design. Stresses were measured simultaneously in the lower flanges of 24 consecutive floorbeams by means of electromagnetic strain gages with oscillograph recordings.

The tests on the floorbeams were made under slowly moving locomotives in order to determine the relative amount of axle load carried by each floorbeam and no effort was made to measure the impact effects in these beams.

The analysis of the data indicates the following:

1. The load on the floorbeams from the locomotive axle loads is not uniformly distributed but varies by 15 to 19 percent from the average in 24 floorbeams. It appears that the stress in every fifth or sixth floorbeam is increased by center-bound or tight ties.

2. The average stress in the floorbeams can be calculated with a fair degree of accuracy by using the AREA design specification recommendations for the distribution of the locomotive axle loads.

Foreword

The data presented in this report were secured during the testing of a 100-ft. through girder span as part of the program for Assignments 2 and 3. The tests were made during the summer of 1947 and were carried out under the general direction of G. M. Magee, research engineer, Engineering Division, AAR. The conduct of the tests, analysis of data and preparation of the report were in charge of E. J. Ruble, structural engineer, research staff, AAR.

The bridge tested was on the main line of the Chicago, Burlington & Quincy Railroad between Omaha, Neb., and Denver, Colo., close to Ft. Morgan, Colo., where several high speed diesel and steam locomotives operate each day. The tests were made under regular scheduled trains; however, arrangements were made with the operating department to have certain trains cross the bridge at various speeds, ranging from 5 mph., which is considered the same as static loading, to the maximum operating speed of the locomotive.

Instruments

The instruments used in these tests were of the electrical type and were fully described in the Proceedings, Vol. 42, 1941, page 402. The gages used were of the electromagnetic type having a 2-in. gage length. Two 12-element oscillographs were used, so stresses were recorded for each test run of the locomotive simultaneously at 24 gage locations.

The relative position of each locomotive wheel with respect to the floorbeams was indicated by a solenoid marker unit in each oscillograph through the use of a spring-type switch located at the center of the span directly over the center line of floorbeam 13 (see Fig. 1), the switch being actuated by each passing car wheel.

Test Span and Location of Gages

The girders and floorbeams tested were built in 1935 and were designed for Cooper E 72 loading. The span consisted of two 100-ft. girders overall, and 98 ft. 4 in. center to center bearings, at 17 ft. 6 in. center to center of web plates. The floorbeams consisted of 18-in. by 55-lb. wide flange beams spaced at 18½ in. centers (see Fig. 1). The deck was of the ballasted type; that is, the track ties supporting the rails rested on 6 in. of crushed rock ballast. The ballast was carried by a ⅜-in. wrought iron floor plate resting directly on the top flange of the transverse floorbeams.

The floor system had one row of diaphragms on the center line of the track consisting of one plate—15 in. by ⅜ in. by 1 ft. 2 in. and two angles—3 in. by 4 in. by ⅜ in. by 1 ft. 2¾ in. The floorbeams were fastened directly to the girder webs by two angles—8 in. by 4 in. by ½ in. by 9 in. long. Knee braces were placed on every eighth beam (see Fig. 1).

The principal purpose of these tests was to determine the distribution of axle loads to the various floorbeams, so the gages were placed to measure the longitudinal bending stress in the lower flange of 24 consecutive floorbeams at the center line of the track. In this manner, the simultaneous static stresses or stresses under slowly moving locomotives could be determined for any position of the locomotive as well as the maximum static stresses in the individual floorbeams. The maximum stresses in the floorbeams under high speed locomotives would occur at a point under one of the rails, depending upon the angular position of the drivers and the rolling of the locomotive.

Test Results

The recorded static stresses in the 24 consecutive floorbeams under three different classes of locomotives are shown in Figs. 1, 2 and 3. The maximum recorded static stress in floorbeam 13, located at the center of the 100-ft. spans, occurred when the third driver (wheel 4) was close to the center of the span, (see Figs. 1 and 3). The stresses in the remaining floorbeams for this position of locomotive are shown by the dashed lines and marked "simultaneous stresses."

The maximum recorded static stress in floorbeam 6 under the class 0–2A locomotive occurred when the third driver was close to this beam and the simultaneous stresses in the remaining floorbeams for this position of the locomotive are shown in the diagram of Fig. 2. The maximum recorded stress in floorbeam 17 under the class 0–2A locomotive also occurred when the third driver was close to this beam and the simultaneous stresses in the remaining floorbeams for this position of the locomotive are shown in the lower diagrams of Fig. 2.

The maximum stresses recorded in the individual floorbeams as the locomotive passed over the bridge are shown by the solid lines in Figs. 1, 2 and 3 and are marked "maximum stresses." The average of the maximum recorded stresses in the 24 floorbeams are indicated by the dotted horizontal lines in each figure. The stresses in the floorbeams under the three locomotive classes, as determined by the recommendation for axle load distribution in the AREA design specifications are also shown on these diagrams by the solid horizontal lines.

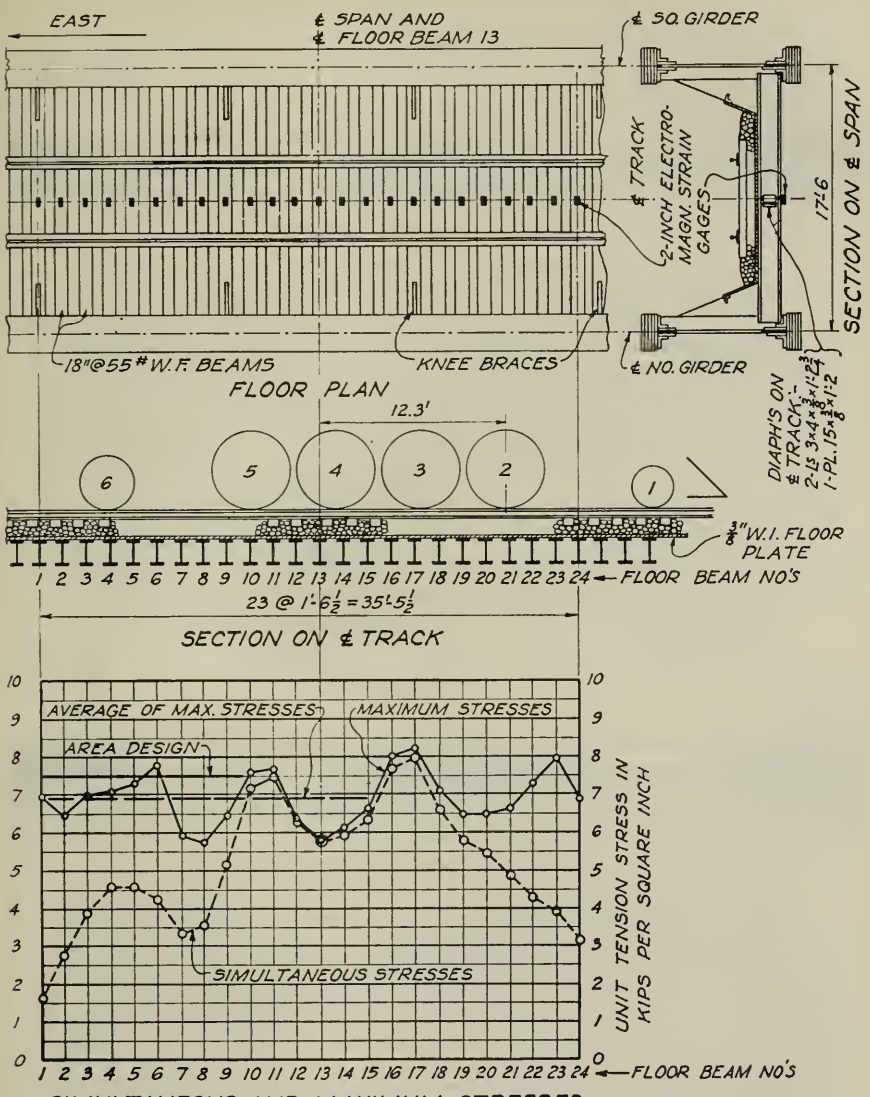
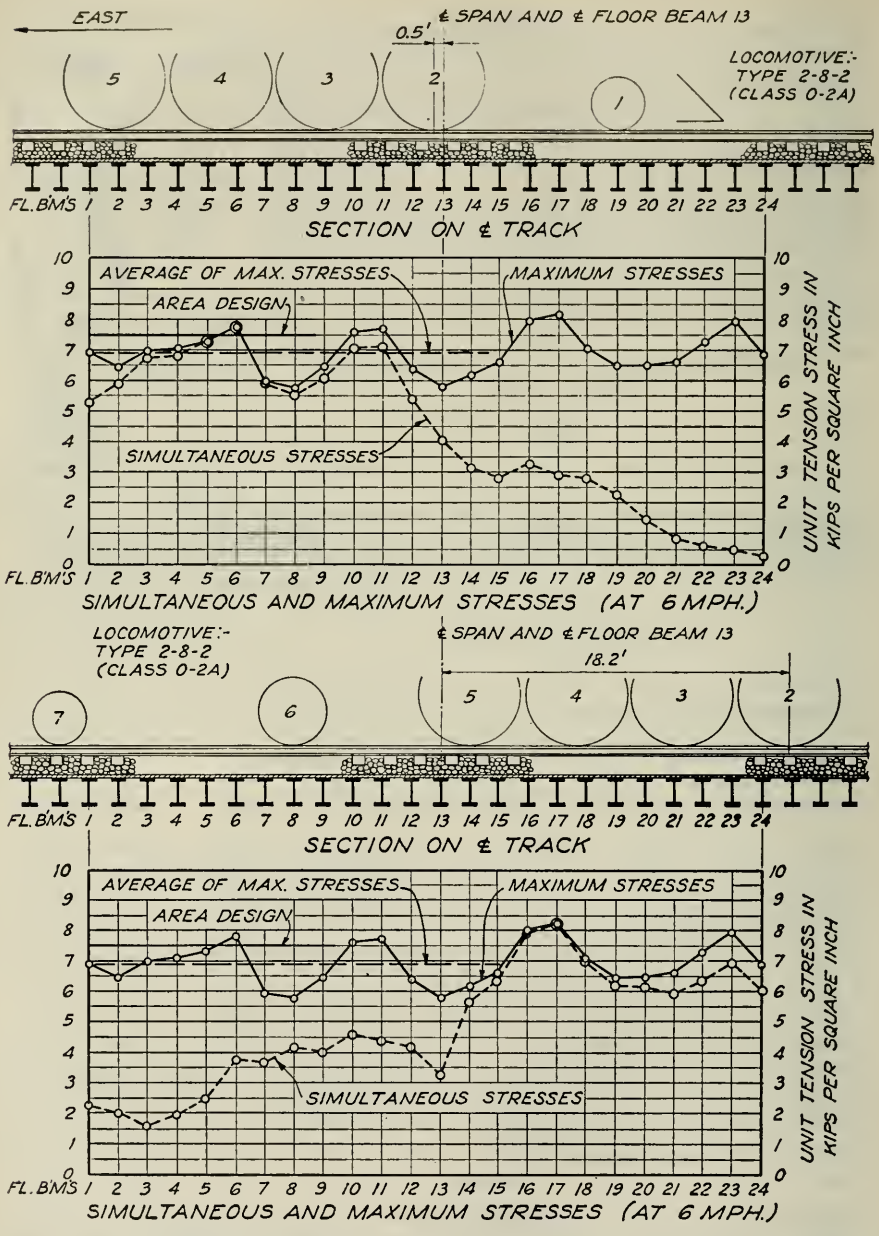
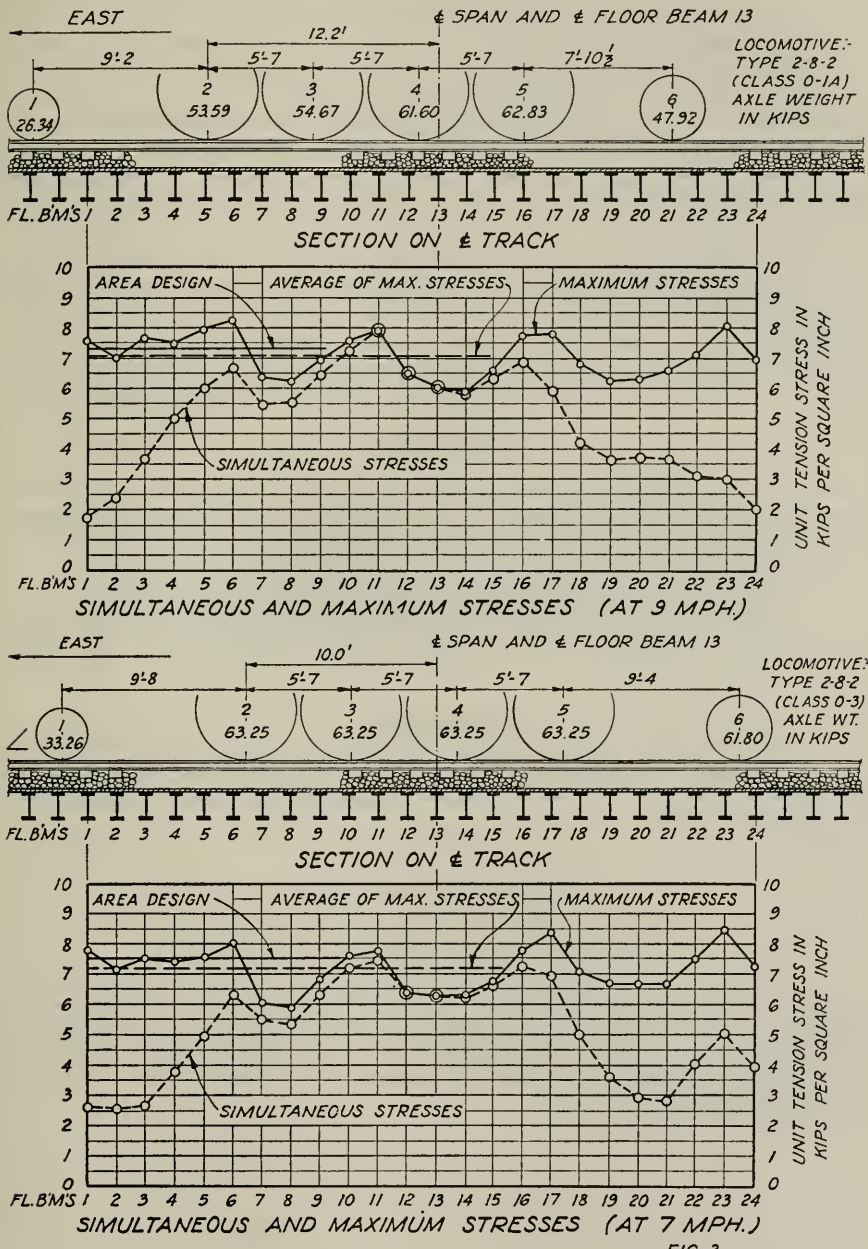

EAST
℄ SPAN AND
℄ FLOOR BEAM 13
℄ SQ. GIRDER
℄ TRACK
2-INCH ELECTRO-MAGN. STRAIN GAGES
17'-6"
SECTION ON ℄ SPAN
18"@55# W.F. BEAMS
KNEE BRACES
℄ NO. GIRDER
FLOOR PLAN
12.3'
DIAPH'S ON ℄ TRACK:-
2-ls 3"×4"×⅜"×1'-2¾"
1-PL. 15"×⅜"×1'-2"
6 5 4 3 2 1
⅜" W.I. FLOOR PLATE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 ← FLOOR BEAM NO'S
23 @ 1'-6½" = 35'-5½"
SECTION ON ℄ TRACK
AVERAGE OF MAX. STRESSES
MAXIMUM STRESSES
AREA DESIGN
SIMULTANEOUS STRESSES
UNIT TENSION STRESS IN KIPS PER SQUARE INCH
0 1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 ← FLOOR BEAM NO'S
SIMULTANEOUS AND MAXIMUM STRESSES
(AT 6 MPH.)
o RECORDED STRESS VALUES
10 9 8 7 6 5 4 3 2 1 NUMBER
43.76 43.76 43.76 43.76 60.00 63.14 63.14 63.14 63.14 32.20 WEIGHT IN KIPS
AXLE
5'-6 5'-6 5'-6 12'-2 9'-4 5'-7 5'-7 5'-7 5'-7 9'-8
TEST LOCOMOTIVE - TYPE 2-8-2 (CLASS 0-2A)

FIG. 1
C.B. & Q. R.R. BRIDGE TESTS
100'-0" T.P.G. SPAN
STRESSES IN FLOOR BEAMS



o RECORDED STRESS VALUES

FIG. 2
C.B. & Q. R.R. BRIDGE TESTS
100'-0 T.P.G. SPAN
STRESSES IN
FLOOR BEAMS



o RECORDED STRESS VALUES

FIG. 3
C.B. & Q.R.R. BRIDGE TESTS
100'-0 T.P.G. SPAN
STRESSES IN FLOOR BEAMS

The maximum stress in all the floorbeams should be about the same as the average of the maximum stresses recorded in the 24 floorbeams, but the greatest stress, which occurred in floorbeam 17, was about 19 percent greater than the average. The only explanation that can be offered for this variation in stress between the floorbeams is that the loose and tight ties have a marked influence on the stresses. In normal track, it is quite common to find about every sixth tie tight and the remaining ties loose. The rail profile and tie play reading taken on ballasted deck bridges and published in the AREA Proceedings Vol. 44, 1943, pages 39, 43, 48 and 49, indicate that the tie play is very irregular.

The calculated stresses in the floorbeams resulting from the axle loads shown for these locomotives, as determined by the AREA design specification, article 204, page 15–6, should equal the average of the maximum recorded stresses since the present specification does not make any allowance for the variation in stresses between the floorbeams. However, for these tests the AREA design allowance is slightly greater than the average indicating that the constant "K" in the distribution equation is slightly high.

Conclusions

These tests afforded an opportunity to measure and compare the simultaneous stresses in 24 transverse floorbeams under any position of the locomotives as well as the maximum stresses in the floorbeams as the locomotive crossed over the bridge.

From the data, as found from these tests, it seems logical to conclude that:

1. The locomotive axle loads are not distributed equally to the floorbeams.
2. There is good agreement between the average of the maximum stresses recorded in the floorbeams and the calculated stresses as determined by the AREA design specifications.

Acknowledgment

The Committee on Impact and Bridge Stresses and the American Railway Engineering Association are greatly indebted to the Burlington Railroad for its cooperation in conducting these tests.

Report on Assignment 11

Stresses in Lateral Bracing of Bridges

The stresses in the lateral bracing and cross-frames of the girder spans have been measured in connection with the tests made under Assignment 2. The test data that have been analyzed so far indicate that the stresses in the lateral bracing and cross-frames are small but these members are subject to considerable vibration. Progress is reported in assembling data on this subject.

Report of Committee 24—Cooperative Relations With Universities

F. R. Layng, *Chairman,*
Lem Adams
L. L. Adams
J. B. Akers
J. B. Babcock
T. A. Blair
H. R. Clarke
R. P. Davis
O. W. Eshbach
W. D. Faucette*
P. O. Ferris
C. G. Grove
E. M. Hastings
Clark Hungerford
R. B. Kittredge
A. A. Miller
S. R. Hursh,
Vice-Chairman,
C. T. Morris
C. H. Mottier
W. C. Sadler
E. C. Vandenburgh
Barton Wheelwright
R. C. White
Committee

* Died May 19, 1947.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Stimulate greater appreciation on the part of railway managements of

   (a) the importance of bringing into the service selected graduates of colleges and universities, and

   (b) the necessity for providing adequate means of recruiting such graduates and of retaining them in the service by establishing suitable programs for training and advancement.

   Progress report, submitted as information ..... page 286

2. Stimulate among college and university students a greater interest in the science of transportation and its importance in the national economic structure, by cooperating with and contributing to the activities of student organizations in colleges and universities.

   Progress report, submitted as information ..... page 296

3. The cooperative system of education for railway service.

   Progress report, submitted as information ..... page 299

4. Investigate textbooks and other material available for instruction in railway engineering, and make pertinent recommendations thereon.

   Progress report, submitted as information ..... page 300

The Committee on Cooperative Relations with Universities,
F. R. Layng, *Chairman.*

AREA Bulletin 471, January 1948.

Report on Assignment 1

Stimulate Greater Appreciation on the Part of Railway Managements of:

(a) the importance of bringing into the service selected graduates of colleges and universities, and

(b) the necessity of providing adequate means for recruiting such graduates and of retaining them in the service by establishing suitable programs for training and advancement.

C. H. Mottier (chairman, subcommittee), H. R. Clarke, C. G. Grove, E. M. Hastings, S. R. Hursh.

This is the second progress report on this subject, presented as information.

Last year's report reviewed past employment practices of American railroads, emphasizing the present need for employment of carefully selected engineering graduates, and the desirable procedure to follow in recruiting such graduates. It was shown that an aggressive employment policy with a starting salary as high or higher than that paid by competing industry, and a prospective future commensurate with the employee's ability, were necessary to attract the better engineering graduates.

In order to ascertain pertinent information as to methods now being employed to interest prospective engineering employees in railroad service, and the salaries being paid to graduates by railroads and other industry, Questionnaire 1, Appendix A, was submitted to railroads and Questionnaire 2, Appendix A, was submitted to engineering colleges and universities.

Questionnaire 1 was sent to all railroads operating more than 500 miles of road in the United States, on July 18, with a cut off date of September 1, 1947, so as to cover salaries paid and employees hired prior to that date. In the review of the following information, it should be borne in mind that the salary data have not been influenced by the 15½ cents per hour pay increase granted non-operating employees, effective September 1, 1947. In relating this information to existing conditions, consideration should be given to that fact, as the recent general increases paid employees on railroads and in other industries, to a large extent, have been reflected in the salaries of engineering employees and should influence the rates paid future engineering graduates.

The term "engineering graduate" as used in Questionnaire 1, includes only recent engineering graduates recruited in the engineering and maintenance of way departments, and does not include employees of the mechanical departments unless such employees had been initially employed by the engineering department.

Replies were received from 45 railroads, but of this number only 33 had hired engineering graduates during 1946 or 1947. These 33 railroads represent more than 2/3 of the Class I railroad mileage in the United States.

Information received as to the number of engineering graduates employed and still in service, together with starting salaries paid, appears in Table 1.

Of the 130 graduates employed in 1946 there were only 88 or 67.7 percent still in service on August 1, 1947. In this relatively short period, which probably averaged approximately one year per graduate, approximately one-third left the service. This, in a very striking manner, calls attention to one of the serious problems faced by the railroads in recruiting engineering graduates. It also raises some interesting questions as to

TABLE 1.—NUMBER AND SALARIES OF ENGINEERING GRADUATES EMPLOYED BY RAILROADS IN 1946 AND 1947

Road No.	Order As To Miles of Road	Year 1946					Jan.—July 1947					Total Number	
		Starting Salaries			Number		Starting Salaries			Number			
		Min.	Avg	Max.	Hired	Still in Service 8-1-47	Min.	Avg.	Max.	Hired	Still in Service 8-1-47	Hired	Still in Service 8-1-47
1	5	227	227	227	17	10	227	227	227	20	18	37	28
2	4	247	287	319	10	8	250	279	309	20	19	30	27
3	3	219	258	295	14	11	219	266	295	10	10	24	21
4	11	220	255	295	16	13	240	257	260	7	7	23	20
5	17	179	278	335	4	4	231	289	340	17	15	21	19
6	12	200	268	308	7	3	218	251	286	14	14	21	17
7	14	216	227	241	9	3	231	235	241	10	10	19	13
8	13	230	254	280	13	8	230	236	260	5	5	18	13
9	7	250	274	309	9	7	254	254	255	7	6	16	13
10	24	218	237	293	4	1	250	250	250	5	3	9	4
11	2	191	211	251	6	2	206	266	325	3	2	9	4
12	8						200	241	300	7	7	7	7
13	10	186	213	240	2	2	204	242	278	4	4	6	6
14	6						291	291	291	6	6	6	6
15	1						224	254	325	6	6	6	6
16	9	219	222	225	2	2	225	230	245	4	3	6	5
17	23	200	203	213	5	5						5	5
18	33	210	210	210	1		210	210	210	2	2	3	2
19	26	195	195	195	1		265	265	265	2	1	3	1
20	32	250	250	250	2	2						2	2
21	18	250	256	262	2	2						2	2
22	20						242	242	242	2	2	2	2
23	22	170	194	218	2	2						2	2
24	25						225	245	265	2	1	2	1
25	31	225	225	225	2	1						2	1
26	28	311	311	311	1	1						1	1
27	16	250	250	250	1	1						1	1
28	27						200	200	200	1	1	1	1
29	21						231	231	231	1	1	1	1
30	29						250	250	250	1	1	1	1
31	30						225	225	225	1	1	1	1
32	15						225	225	225	1	1	1	1
33	19						274	274	274	1	1	1	1
Totals					130	88				159	147	289	235
Weighted Average Salaries			247					255					

why there should be such a heavy turnover of newly employed graduates, where the fault lies, and how it can be remedied. It shows clearly that there is not only the problem of recruiting the graduate, but of retaining him in service after he is once employed.

It is interesting to note that in the first seven months of 1947, 159 graduates were hired as compared to 130 in the entire previous year. As might be expected, there seems to be a reasonably close relation between the size (miles) of the railroad and the number of graduates employed.

As previously stated, it should be borne in mind that the salaries recorded in Table 1 were all effective prior to the 15½ cents per hour ($31.62 per month) increase awarded the non-operating groups by the arbitration board, effective September 1, 1947. As the April 1, 1946 award was retroactive to January 1, 1946, and as it is reasonable to suppose that very few graduates were employed in the first three months of 1946, it follows that the period covered by the questionnaire was undisturbed by any general wage increase effective on the railroads. It also follows that the 15½ cents award to nonoperating groups, together with the upward trend in living costs, will necessitate an upward adjustment in salaries paid graduates in the first half of 1947, as reflected in Table 1, to be comparable with salaries now paid engineers by the railroads and by industry in general.

A comparison of the salaries paid in 1946 with those paid in the first half of 1947, indicates an upward trend. The weighted averages for the two periods are $247 and $255 respectively. This upward trend is more pronounced in the minima than in the average paid, the weighted average minima for the two periods being $222 and $236 respectively. This trend is further evidenced by the fact that five roads employing a total of 15 graduates in 1946 paid seven of them less than $200 per month, and in 1947 four of these roads employed a total of 26 graduates with a weighted average minimum rate of $234. The fifth road did not employ a graduate in 1947, and in no case was the 1947 rate less than $200. Fifteen reporting roads employed graduates in both years. The minimum initial salaries paid by four of these were the same in 1947 as in 1946, while on the other 11 the minimum salary was increased. In no case was the initial salary reduced.

Speaking generally, the salaries paid engineering graduates in the first half of 1947 averaged approximately $255 with a maximum on four railroads exceeding $300.

Of the 34 railroads answering Question 8, "Have you been able to secure enough graduates at the rate you paid in 1946 and 1947 to meet your requirements?," two replied conditionally, and of the remainder, 10 replied in the affirmative, and 22 in the negative.

Several of the 32 roads answering Question 9 gave such wide ranges for starting salaries necessary to attract promising graduates, that it is difficult to summarize results in an effective manner, and in making the analysis two railroads that gave ranges in excess of $50 were eliminated so as to permit more definiteness in analyzing replies. Of the remaining railroads, eight gave ranges that extended below $250, 16 gave salaries between $250 and $275 and six others extended their range of salaries to $300.

Table 2 summarizes the methods used in recruiting graduates and the number so recruited as reported by the 30 roads replying to Question 4.

Methods of recruiting engineering graduates by industry generally (not limited to railroads) were investigated in a questionnaire sent in May 1946, to employers of engineers by the Engineers' Joint Council Committee on the Economic Status of the Engineer. The results indicated that 70 percent of employers send representatives to interview the prospect at school. Table 2 indicates that only ten railroads or 30 percent

TABLE 2.—METHODS USED BY RAILROADS IN RECRUITING ENGINEERING GRADUATES

Method	Number of Roads Using Method Indicated	No. of Graduates Hired by Roads Indicated	
		By Method Indicated	Total Hired by All Methods
Application initiated by applicant	25	133	232
Faculty member acting as intermediary	13	64	148
Railroad representative interviewing prospect at school	10	70	181
Contacted through friends	1	6	18
By paid advertisements	3	5	30
Graduate interviewed at railroad office	1	1	1
Persons employed returning to service	1	1	1

recruited engineering graduates by this method and that only 24 percent of their recruits were thus employed. The Engineers' Joint Council Committee reported further that 51 percent of the employers invite students to visit their plants at company expense. These facts would indicate that the railroads are far less active in recruiting graduates than is industry generally.

Only one railroad stated that it used an aptitude test in determining the fitness of the graduate.

Of the 39 railroads replying to Question 5, which related to pre-graduate training, only 13 reported a vacation training program for undergraduate students. However, of those not having a training program, four employed students during summer vacations.

In reply to Question 7, 31 railroads stated that they do not have a definite schedule for advancing the rate of newly employed graduates, or merely gave the answer "variable," and can therefore not be tabulated. Seven railroads did give specific information in reply to the question. This information is presented in Table 3.

TABLE 3.—PROGRAM FOR SALARY ADVANCEMENT

Railroad No.	Average Starting Salary		Total Number of Graduates		Program for Salary Advancement
	1946	1947	Hired	Still in Service 8-1-47	
1	227	227	37	28	After 6 months $15 After 12 months 25 After 30 months 25
10	237	250	9	4	After 6 months 25
18	210	210	3	2	After 6 months 15 After 12 months 25
19	195	265	3	1	After 6 months 5 After 12 months 10 After 18 months 10
20	250	----------	2	2	After 6 months 25 After 18 months 25
28	----------	200	1	1	After 12 months 25
32	----------	225	1	1	After 12 months 25

In reply to Question 10, numerous reasons were given as to why the carriers are unable to recruit a sufficient number of graduates or retain them permanently after employment. These are summarized in Table 4.

TABLE 4.—REASONS FOR THE INABILITY OF RAILROADS TO EMPLOY AND RETAIN ENGINEERING GRADUATES

Reason	*Total Number of Railroads Giving the Reason Indicated*
Other industries pay higher salaries	14
Lack of opportunity for advancement on railroads	8
Lack of automatic or systematic promotion on railroads	5
More stability of employment in other industries	4
Other industries have more attractive working conditions	3
Housing shortage	3
Lack of opportunity for advancement on railroad in other than the engineering department	3
Too much hard work	2
Lack of special training courses	2
Shorter working hours in other industries	1
Lack of personnel relations which would place employee in work where his talents can best be exercised, thus insuring job satisfaction	1
Lack of opportunity to establish normal family and community life	1
Lack of increases in salary commensurate with progress	1
Higher deductions for Social Security than in other industries	1
Restrictions imposed by agreement with technical employees	1

In addition to the foregoing summary it will be interesting to note the specific comments of a few of the replying railroads.

Chief Engineer of Railroad No. 1.—If the railroads are to attract and hold in their employment the caliber of men they must have to retain their pre-eminent position, they must be prepared to compete with the best of private industry. Factors are such things as:

(a) Initial starting salary.
(b) Automatic promotion up to a certain point.
(c) Stability of employment and place of employment.
(d) Limited working hours.
(e) Opportunity for advancement within the organization in other than strictly engineering work.
(f) Special training course within the company.
(g) Enlightened personnel relations to insure that proper recognition is given to the competent young executive, both to the extent of placing him in the work where his talents can best be exercised, thus insuring job satisfaction.
(h) Giving opportunity for advancement up to the limit of ability to insure high morale.

Chief Engineer of Railroad No. 6.—Starting salaries offered to college graduates have been acceptable in most cases, but difficulties in attracting and holding men are due principally to:

(a) Unwillingness to travel and the attendant lack of opportunity to establish normal family and community life. This is true of married as well as unmarried men.
(b) Definite promise by other industries of systematic and periodic promotions.
(c) The widespread belief that, after a number of years of experience, men in other industries are likely to have advanced further in responsibility and income.

(d) More attractive positions in other industries offering better opportunities, more compensation and a greater feeling of security.

These observations resulted from interviews in an intensive effort to secure new engineering employees, not limited, however, to 1947 graduates. Four universities were canvassed, and of the 1947 civil engineering graduates, only 24 showed any interest in railroad work. Of these 24, we succeeded in employing only four.

Chief Engineer of Railroad No. 25.—From inquiries and applications and some interviews it is thought that to attract men of reasonable ability and stability it is necessary that the railroads afford assurance of definite schedule of advancement in rank and increase in salary over a definite period, and assurance that the engineering personnel will not be arbitrarily reduced merely to effect a payroll reduction to accompany a recession in gross revenues regardless of the current or prospective value of the individual to the railroad. The railroads are suffering from their policy of the past and unless that policy is modified it is obvious that they will continue to suffer.

Assistant Chief Engineer of Railroad No. 16.—Early this year, a number of engineering schools located in the territory served or near our lines were advised that we had vacancies in several branches of our engineering organization for engineering graduates and requested that if any of the senior students were interested that they contact us prior to graduation. Replies received from various schools indicated that other industries were making a concerted drive for engineering graduates and most of them had representatives interview the students. In general, their propositions were more attractive than we could offer. We did have one representative interview a number of graduates at one school and were informed that one or two other railroads had done likewise. Most of the students contacted, either through correspodence or personally, indicated they were shopping around and had not definitely made up their minds as to their career. In other words, it is still a seller's market as far as engineering graduates are concerned.

Chief Engineer Railroad No. 21.—In my opinion the only way graduate engineers will be attracted to the railroads in the future, is to have a minimum starting salary, with a graduated increase yearly or semiyearly up to a maximum in each class and then promote them to a higher class after serving a certain time as understudies to the higher class. This would necessitate a closer cooperation between railroads and local colleges or universities, and a definite plan of programmed increase in compensation and promotion for the graduate.

Chief Engineer of Railroad No. 11.—Our technical men are organized and that has had the effect of greatly restricting our activity along the lines of encouraging engineering students to enter our service . . .

Our greatest obstacle is our inability to advance college graduates owing to the restrictions imposed by seniority rules. If we were not so restricted, we feel that we would be able to attract more young men, possibly not enough. Outside concerns, such as the oil companies, states and municipalities have drawn heavily from recent college graduates. Possibly, within the next two or three years, we can look forward to an increasing number of college graduates and that might relieve our situation. Technical railroad employment offers attractive opportunities to young college graduates who have the characteristics of a railroader.

In last year's report reference was made to information collected on salaries of engineers by the Engineers' Council of Professional Development. That information,

which was as of May 1, 1946, indicated that salaries paid inexperienced graduates ranged from $150 to $261, with an average of $206 per month. With a view of collecting more up-to-date information, and limiting it to only civil engineering graduates, Questionnaire 2 was submitted to and answered by 62 engineering colleges and universities. Of this

TABLE 5.—NUMBER AND SALARIES OF CIVIL ENGINEERS GRADUATING IN FIRST SEVEN MONTHS OF 1947

College or University No.	Total Number of Graduates in Class	All Civil Engineering Graduates				Graduates Employed by Railroads			
		Starting Salary			Number on which average is based	Starting Salary			Number on which average is based
		Min.	Avg.	Max.		Min.	Avg.	Max.	
1	84	230	260	290	84				
2	78	175	225	285	78	250	250	250	1
3	50	200	225	375	50	185	225	275	3
4	55	225	260	300	50	0	0	0	0
5	66	200	271	600	40	264	280	285	9
6	38	220	260	300	38	0	0	0	0
7	35	250	300	350	35	0	0	0	0
8	30	210	250	350	30	260	300	340	2
9	76	225	270	350	27				
10	31	240	260	325	27	200	248	275	4
11	43	250	300	450	27	0	0	0	0
12	28	183	225	300	25				
13	68	200	258	350	23	226	226	227	2
14	35	200	230	250	20	0	0	0	0
15	20	250	258	317	20	0	0	0	0
16	36	225	250	325	20	250	280	325	5
17	30	225	235	275	20	225	225	225	3
18	19	225	235	275	19	0	0	0	0
19	19	225	260	300	19	0	0	0	0
20	32	220	251	290	17	260	268	275	2
21	31	200	256	318	16	234	260	291	3
22	16	240	250	300	16	0	0	0	0
23	24	200	225	250	15	0	0	0	0
24	22	180	240	325	15	0	0	0	0
25	36	235	275	300	14	265	265	265	1
26	30	175	250	300	13	0	0	0	0
27	13	250	268	300	13	0	0	0	0
28	13	225	230	268	13	0	0	0	0
29	12	225	270	300	12	0	0	0	0
30	22	204	238	303	12	0	0	0	0
31	16	247	274	320	11	281	281	281	1
32	11	220	240	267	11	0	0	0	0
33	11	200	245	300	11				
34	11	200	250	275	11	0	0	0	0
35	12	220	290	346	11	0	0	0	0
36	17	200	252	275	10	227	251	275	2
37	16	200	248	325	10	200	238	271	4
38	11	180	250	450	10	0	0	0	0
39	10	235	267	315	9	235	270	295	3
40	22	263	275	466	8	0	0	0	0
41	16	235	255	280	8	235	235	235	1
42	8	200	265	360	8	250	250	250	1
43		225	250	275	6	0	0	0	0
44	7	225	240	300	6	231	231	231	1
45	13	200	240	310	5	0	0	0	0
46		225	256	303	5	0	0	0	0
47	4	225	250	300	4	0	0	0	0
48	10	203	212	221	2	203	212	221	2
49	2	250	250	250	1	0	0	0	0
50		225	240	260		221	240	250	3
51		200	230	250					
52	17	200	250	320					
53		185		400					
TOTALS					955				53
Weighted Average Salaries			253				256		

Note: In computing weighted average salaries, only those schools were used on which the number of graduates involved was available.

number, however, only 53 gave the information requested in such shape that it could be tabulated as shown in Table 5. In the case of some schools, the salaries paid the graduates entering railroad employment could not be accurately segregated.

Table 5 indicates that the average starting salary of the 955 civil engineering graduates reported on was $253 with a minimum of $175 and with 35 of the 53 schools reporting maxima ranging from $300 to $600. The information furnished on railroad employment covered such a small sampling that any conclusions from the college questionnaire as to salaries paid to its graduates entering railroad service might be misleading. Only four colleges reported having as many as four graduates entering railroad service and the total reported by the 20 schools was only 53. The average starting railroad salary ($256) was practically the same as the average of all the civil engineering graduates reported ($253). A comparison of the maximum salaries indicates that the higher salaries, which presumably went to the better graduates, were paid by industry generally and not by the railroads.

The following are a few representative comments submitted as replies to Question 5 of Questionnaire 2.

College 26.—There is a general feeling among our engineering graduates that the railroad industry is not particularly interested in university graduates and that it has done little to make it an attractive engineering opportunity. I believe that this attitude could be easily changed by an aggressive recruiting program. (Note—None from this college entered railroad service.)

College 38.—There was a shortage of men in this area and the graduates took the high salary jobs. The railroads will have to pay $275–$325 in order to get graduates if the present trend continues. (Note—None from this college entered railroad service.)

College 24.—In spite of the fact that several roads visited us and offered men jobs not one man accepted.

It was not just the higher wages offered by business and industry that attracted our men away from railroading. They disliked the seniority system which prevails and felt it would interfere with incentive—not as much for the junior engineer as in the long run.

College 22.—We have definitely tried to encourage our men to take work with railroads, but with little success. The present men graduating are largely GI's who have done a lot of traveling and want to settle down. Hence the travel involved in the usual railroad job was not inviting to them. Men in former classes who have gone with the railroads all seem to be happy with their jobs.

College 31.—Although a number of railroads contacted this office in regard to hiring seniors, the majority involved an apprenticeship program in which salary was considerably lower than that generally encountered in other industries; therefore, there was considerable reluctance among the students to accept this sort of work.

College 5.—This year there seems to be a revival of interest in railroad work among our civil engineering students. I attribute this to the appreciable increase in starting salaries which a few of the railroads are offering our men this year. During the past few years, I have noticed a tendency on the part of our civil engineering graduates to shy away from both railway and highway work principally because of the low starting salaries offered.

Assuming you wish me to speak freely on this matter of engineering employment with railroads, I should like to make the following observations:

1. Beginning salaries in railroad work must be kept close to beginning salaries offered in other engineering fields if the railroads expect to get our better engineering graduates.

2. The necessity for frequent moves of family and household goods, particularly in maintenance of way work, deters many of our graduates from accepting this type of employment. Just yesterday, I learned of one college graduate on railroad work who had been compelled to move 18 times in 12 years. With the present shortage of housing, this is a terrific handicap.

3. In maintenance of way work, the necessity of "being on call" for 24 hours a day and seven days a week, does not appeal to some of our graduates.

4. One of my pet peeves is the amount of red tape and delay encountered in having a senior finally accepted for employment with some railroads. We have had representatives come here to interview our seniors who tell us frankly that they can make no definite commitments, but are merely here to interview the men, take notes on their capabilities and pass them on to their immediate superior. This superior passes his recommendations on through channels until finally it reaches the chief engineer or some other high official who has a final say on employment. Several weeks may elapse before the interested senior receives a definite offer from headquarters, and by that time he usually has become disgusted and has signed up for employment elsewhere. If the railway representative sent here to interview students could be given authority to actually sign them up after he is convinced that they are the type of men his company wants, then I feel sure you would get more of our civil engineering graduates into railroad work.

5. I continually urge our boys to give consideration to railway employment, emphasizing the advantages of a career in railroad work and the present possibilities for rapid advancement due to the wide gap in age ranges brought about by the limited employment of civil engineers during the depression and during the war period.

6. It is my feeling that a closer check on the progress and attitudes of these young engineering employees with a more positive guidance program on the part of the railroad companies would aid greatly in attracting and holding some of our better men in railroad work.

Appendix A

Questionnaire 1

1. Name of Railroad
2. Officer answering questionnaire
3. Indicate starting rates, titles and number of graduates* hired in years 1946 and 1947.

Starting Title	*Starting Rate*	*Year 1946*		*Jan. 1, 1947 to Date*	
		Number Hired	*No. Remaining in Service*	*Number Hired*	*No Remaining in Service*

4. Indicate number hired since January 1, 1946 classified under the following methods of initiating contacts with graduates:
   (a) railroad representative interviewing prospect at school .....
   (b) faculty member acting as intermediary .....
   (c) application initiated by graduate .....
   (d) any other methods (name methods and number hired under each method) .....
5. Do you have a program for pre-graduation training through:
   (a) summer vacation employment
   (b) arrangement with one or more engineering schools for alternating periods of schooling and on-the-job training (often referred to as the "Antioch Plan")
6. Do you use any sort of aptitude test to determine whether an applicant is temperamentally fitted for railroad work?
7. Do you have a definite schedule for advancing newly employed graduates, and if so, what is the period of each advancement and the increase in salary? If the advancement involves a change in title please so state.
8. Have you been able to secure enough graduates at the rates you paid in 1946 and 1947 to meet your requirements?
9. Based on your contact with prospective graduates and faculty of colleges and universities what starting salary, in your opinion, is required for the railroad to attract promising graduates?
10. Would be pleased to receive any comment you might care to offer on related phases of this subject such as why you were not able to employ a sufficient number of graduates, reasons why those you employed have quit, etc.

* The term graduates as used in this questionnaire means recent graduates with not more than one year's experience since graduation from a university or technical college of recognized equivalent standing.

Questionnaire 2

1. Name of institution .....
2. Officer answering questionnaire .....
3. Indicate salaries paid *this year's* graduates receiving bachelors degrees:

	All Civil Engineering Graduates	*Graduates Employed by Railroads*
Maximum salary		
Minimum salary		
Average salary		
Number of graduates on which average is based		
Total number of graduates in this year's class		

4. Indicate salary paid each one of this year's graduates in civil engineering who entered railroad work. This is to cover those included in the last column in question 3.
5. Remarks:

Report on Assignment 2

Stimulate Among College and University Students a Greater Interest in the Science of Transportation and its Importance in the National Economic Structure

By Cooperating with and Contributing to the Activities of Student Organizations in Colleges and Universities

R. P. Davis (chairman, subcommittee), L. L. Adams, T. A. Blair, Barton Wheelwright.

The activities of this subcommittee during the past year were largely concentrated on making arrangements to have railroad speakers appear before student groups. This called for a considerable amount of correspondence with faculty members to secure invitations and a like amount of correspondence with railroad representatives in order to secure speakers.

Letters were sent to the faculty advisers of the student chapters of the American Society of Civil Engineers in 46 representative institutions. As a result of these letters, 18 institutions expressed an interest in having speakers sent to them. Greater difficulty was found in procuring speakers than was experienced in getting invitations. E. M. Hastings, past president of the AREA, was particularly helpful in aiding us to secure speakers. To date, speakers have appeared before student chapters in 13 institutions. During this winter and the coming spring, we hope to place speakers in the remainder of the schools that showed an interest, and we also hope to interest more schools.

The schools at which appearances have been made include the Polytechnic Institute of Brooklyn, the Rensselaer Polytechnic Institute, the University of Cincinnati, the Citadel in South Carolina, the University of Illinois, the University of Louisville, the University of Maine, Rutgers University, the University of Tennessee, Virginia Military Institute, West Virginia University, the University of Wisconsin and Yale University. All visitations except those at Virginia Military Institute and Yale University were arranged by this committee.

Your committee has close contacts with five additional institutions, namely, Massachusetts Institute of Technology, Northwestern University and Ohio State University, the University of Michigan and University of Iowa, through Professor J. B. Babcock of M. I. T., Dean O. W. Eshbach of Northwestern, Professor C. T. Morris of Ohio State, Professor W. C. Sadler of the University of Michigan and Professor R. B. Kittredge of the University of Iowa. These men are members of Committee 24 and are active in bringing the message from the railroads to their schools.

We also have good contacts with Canadian schools through Barton Wheelwright of your subcommittee. He is a member of a committee organized by the Engineering Institute of Canada to contact Canadian universities with a view to advising the students as to the requirements and opportunities of the various lines of engineering work. Mr. Wheelwright represents railroad engineering work on this committee. He is also a member of a committee organized by the McGill Graduates Society to deal with placement problems.

Speakers for the Polytechnic Institute of Brooklyn and for Rensselaer Polytechnic Institute were furnished through the help of R. E. Dougherty, vice-president, New York Central System. M. C. Smith, special assistant engineer of that railroad, spoke before the

Polytechnic Institute of Brooklyn Student Chapter ASCE on April 10, 1947. M. B. Pfeffer, secretary of the student chapter, reports that "Mr. Smith gave a very interesting talk dealing with the opportunities for the civil engineer on the railroad and types of problems he will meet. The subject was one on which the students had given little previous thought, but I feel certain that their interest toward seeking employment with railroad companies has been kindled."

On the same date, A. D. Wolff, Jr., research engineer of the New York Central System, appeared before the student group at Rensselaer Polytechnic Institute. Mr. Wolff explained the active interest now being taken by railroads in recruiting civil engineering graduates due to vacancies that will occur within the next decade by reason of retirements and the lack of new engineers in the lower age brackets. He was asked questions on salaries and methods of securing employment during the summer months. Professor H. O. Sharp, acting head of the Department of Civil Engineering, reported that the meeting was very interesting.

On March 1, 1947, E. S. Birkenwald, engineer of bridges, Southern Railway System, and chairman of Committee 15, AREA, spoke before the University of Cincinnati Student Chapter ASCE. This meeting was arranged through the cooperation of R. W. Renn, associate professor, Department of Coordination at that institution. Mr. Birkenwald spoke on some of the newer developments in railroad construction and maintenance to illustrate the progressiveness of the railroads with the view of showing that railroads are good companies to work for. Both students and faculty members showed considerable interest in the address. One result was the decision by one student to become a student apprentice with the Southern Railway.

R. L. Groover, chief engineer, Atlantic Coast Line Railroad, was the speaker on May 1, 1947, before the Citadel (South Carolina) Student Chapter ASCE, of which Professor H. Gale Haynes is the faculty adviser. Mr. Groover explained the needs of the railroads in securing well-trained engineering graduates. He also went into the many problems connected with maintenance work, with special reference to rails, ties and track fastenings. He also showed how the railroads are now availing themselves of our recently developed knowledge in the field of soil mechanics.

T. A. Blair, member of Committee 24, spoke before the senior civil engineering students of the University of Illinois on practices of the Santa Fe System. The meeting was arranged through Professor W. C. Huntington.

The meeting at the University of Louisville was held on March 5, 1947, and was made possible through the cooperation of C. H. Blackman, chief engineer, Louisville & Nashville Railroad, L. L. Adams, assistant chief engineer of the same railway, and Professor W. R. McIntosh, faculty adviser of the University of Louisville Student Chapter ASCE. Mr. Blackman was originally scheduled as the speaker, but was unable to be present at the date set for the meeting. L. L. Adams kindly consented to take his place. After the meeting, Mr. Adams reported as follows: "I was glad to have this opportunity to present to this group the advantages that would obtain to them by entering the service of some railroad, and from the questions asked, all of the men appeared to be interested, and also indicated that they knew very little about the advantages of such services.

"During the past two or three years, I have been visiting periodically a number of the universities in the South, and I believe that I have been able to create some interest in the graduates as to the advantages of railroad services.

"I believe that if we all will make a particular effort to keep these men informed, we will be able to employ a number of the best men, rather than have them all go to other industries."

The Virginia Military Institute makes it a general practice to have railroad speakers. H. A. DeButts, vice-president, operation, Southern Railway System, spoke before the 1946 annual Student Conference ASCE of V. M. I., V. P. I., and the University of Virginia. In a letter dated January 1, 1946, Col. R. A. Marr, Jr., professor of civil engineering at the Virginia Military Institute, reported that L. M. Griffin, assistant research engineer of the Chesapeake & Ohio Railway had been invited to give a talk in March. Col. Marr wrote further that "each year I find it increasingly hard to persuade my best young graduates to enter this type of work (railroad) . . . May I give you two suggestions which I hope you will pass along to your railroad friends and fellow committeemen.

"Start hiring good college boys for summer work. That way you can give the railroad a chance to try the boy out. Aim your boys at maintenance of way or operation and not at the engineering department.

"There is something radically wrong with some railroads from the following standpoint . . . I cite the case of why two very able young engineers left a prominent eastern railroad. They were getting up at 6:00 a.m. to catch a work train, getting home at 8:20 p.m. every night, six days a week. On Sundays they reported to the office and stayed there until 11:00 a.m. A man cannot be expected to have any family life or be happy on a schedule like that, no matter what you pay him."

Through the cooperation of the Boston & Maine Railroad, a speaker was furnished the University of Maine Student Chapter ASCE. T. G. Sughrue, chief engineer of that railroad, secured the services of J. W. Wiggins, assistant to chief engineer, of the same railroad.

Professor W. S. Evans, Head, Civil Engineering Department, made the arrangements for the university. He reported that Mr. Wiggins gave a very interesting talk, based largely on that railroad's new training program for young engineers. Professor Evans further reported that one or two of his students were somewhat interested in going into railroad work but they finally decided on another field.

The Rutgers University Student Chapter ASCE, Professor F. C. Mergain, faculty adviser, was visited on May 19, 1947 by S. R. Hursh, assistant chief engineer, maintenance, Pennsylvania Railroad and a member of Committee 24. Mr. Hursh talked on the importance of the transportation problem in this country. He outlined the accomplishments of the past and the problems of the future, stressing the opportunities in railroading, not alone from a strictly engineering standpoint, but also from the managerial end.

On June 26, 1947, G. L. Sitton, assistant chief engineer, Southern Railway System, delivered an address before the University of Tennessee Student Chapter ASCE. The meeting was arranged through the help of A. T. Granger, professor and head of civil engineering at the University of Tennessee. Professor Granger summarized the results of the meeting as follows:

"Mr. Sitton spoke on the opportunities for young civil engineers with the railroads, with particular reference to the training program of the Southern Railway in regard to track work and other opportunities with that railroad. He also discussed the general characteristics of a good engineer.

"The general reaction of the students was quite favorable and they were much interested, but I do not believe that many, if any, are likely to be interested in beginning with the railroads on a training program involving track work under the present condition of opportunities of various other types. Recently, however, we have had a number of our graduates go into railroad work in the bridge department."

On April 14, 1947, F. R. Layng, chairman of Committee 24, gave an inspiring talk before an audience of about 140 engineering students comprising the General Engineering Society at West Virginia University. He dwelt at some length on the opportunities presented by many railroads to young engineering graduates resulting from the fact that during the depression years and the war years, very few engineers entered railroad service. Able young men now starting railroad work may expect to advance more rapidly than in the past, as older men reach the retirement age.

Mr. Layng then showed moving pictures of maintenance work with particular reference to laying of jointless rails. He also visited the senior class in railroad engineering and the students spent a very profitable hour with him in a general question and answer forum.

A great deal of interest, particularly on the part of the civil engineers, was aroused by Mr. Layng's very able and inspiring talks. As a result of his persuasive arguments, three men out of a graduating class of ten civil engineers in June 1947 accepted positions with railroads.

Secretary W. S. Lacher of the AREA was the speaker before the civil engineering group at the University of Wisconsin on May 1, 1947. The meeting was arranged through Professor James G. Woodburn, faculty adviser for the ASCE Student Chapter at that institution. His talk was devoted to an exposition of the research program of the Engineering Division, AAR. He explained the relationship between the AREA committees and the research staff of the Engineering Division to show how the AREA fits into the picture. His main purpose was to stress the amount of truly scientific work that is being done on problems relating to railway tracks and structures.

C. W. Dunham, associate professor of Civil Engineering at Yale University, notified your subcommittee that C. E. Smith, vice-president of the New York, New Haven & Hartford Railroad, gave an interesting lecture on railroad engineering to the Yale Student Chapter ASCE during the first semester of 1947–1948.

Report on Assignment 3

The Cooperative System of Education for Railway Service

O. W. Eshbach (chairman, subcommittee), Lem Adams, P. O. Ferris, A. A. Miller, E. C. Vandenburgh.

This is a progress report presented as information.

Since the beginning of cooperative education at the University of Cincinnati over 40 years ago, this method of engineering education has grown to include approximately 10 percent of the engineering schools and a comparable percentage of the total enrollments.

In past reports of the committee, attention was called to the value of this procedure in the development of technical personnel in American railways. Last year the comprehensive statement of what was meant by cooperative education, its ideals and objectives, was prepared by the committee. It would be logical to follow this report with a summary of the degree to which railroads are now participating in cooperative education. Unfortunately, a current report of this nature would not be significant because the schools have not yet been able to return to normal, or pre-war, operation.

During the war, selective service regulations were such that cooperative procedures were entirely suspended for students eligible for military service. In most schools, however, the program was continued for those physically disqualified for service.

Last year, when veterans returned, it was the policy of the institutions, because of the percentage of married veterans, their added maturity, scarcity of housing facilities, and other factors, to give them the opportunity of finishing school as soon as possible. Thus, during the past year, enrollments in cooperative education were at a very reduced level.

Beginning in the fall of 1947, active measures were taken to return to normal procedure. During the present academic year, therefore, increasing numbers of engineering students will be placed in industry on the cooperative basis.

While it was not possible to appraise the degree to which the railways are participating because of the shortness of time, discussions with many men responsible for the placement of students indicate that the railroads are active participants. It will be possible in another year to analyze and report on the kind and extent of this participation.

In reporting on cooperative education, it is pertinent to emphasize that this is but one method of providing concurrent education and experience during the formative period in the lives of young engineers. For many years, individual railway companies have employed engineering students during summer vacations. This, and also the employment of faculty members during vacation periods, is regarded as being mutually beneficial to the railway industry and education.

One of the most important advantages both of cooperative education and summer employment is the discovery before permanent employment of those interested in the business, thus adding stability to employment procedures.

The shortage of engineers at the present time and the consequent competitive situation are matters of concern to employers and educational institutions. An appraisal of how long this situation will last is complicated by the lack of knowledge of the future needs of federal, state, and municipal agencies, and also the timing of construction of facilities for the many industrial research and development programs planned by industry at the close of the war.

A preliminary survey of American industries and present engineering enrollments (approximately 220,000 students) indicates that the supply of graduates will overtake the demand in the year 1950. While it is probable that in the years 1950, 1951, 1952 the number of graduates will exceed the number of positions immediately available, it is possible, nevertheless, that the surplus will be small or completely absorbed within a short period. The situation is being studied by the Manpower Committee of the American Society for Engineering Education. A report of this committee will be published in the Journal of Engineering Education during the winter or early spring and should be of interest to members of the American Railway Engineering Association.

Report on Assignment 4

Investigate Textbooks and Other Material Available for Instruction in Railway Engineering and Make Pertinent Recommendations Thereon

J. B. Babcock (chairman, subcommittee), E. M. Hastings, C. T. Morris, W. C. Sadler.

Last year, this subcommittee presented data as to the courses in railway engineering and other forms of transport which were being offered in the engineering colleges in the United States. A summary of that report showed: (1) Instruction in railway engineering has been reduced to a large extent or entirely eliminated in a number of colleges;

(2) there is a definite trend toward the adoption of courses in transportation engineering covering all forms of inland transport; (3) highway engineering is included in almost all civil engineering curricula, either as a separate subject or in a transportation engineering course; and (4) increasing attention is being given to airport engineering in the current programs. It was found that about one-third of the colleges offer a transportation engineering course either on a required or elective basis. Specific courses in railway engineering are given in less than one-quarter of the colleges; of these, only about half are required subjects. No courses in railway or transportation engineering are offered in nearly half the engineering schools, although practically all of them require civil engineering students to take a course in highway engineering.

This year's report includes a bibliography prepared by the subcommittee to indicate what sources of material are available for instruction in railway engineering. It includes: Books on railway engineering and maintenance of way and on route surveying and location; handbooks which include some railway engineering material; publications of railway organizations; and periodicals. Few of these books or publications would serve as single texts for a course in railway engineering. They do, however, include much valuable information which is available to an instructor for the preparation of courses, and some of them could be assigned as reference books.

The subcommittee has found that there is little uniformity in the scope of the courses now offered in railway engineering. In several colleges the courses include such topics as maintenance of way, signals, yards and terminals, locomotive capacity, train resistance and tonnage rating, velocity profiles, and economics of line and grade revision. But in other cases the content is apparently limited to location surveys, grades, vertical curves, spirals and earthwork—subjects which are usually included in route surveying courses applicable to both railways and highways.

No One Course Applicable in all Cases

The colleges have sometimes suggested that railway groups such as the AREA should indicate what should be included in courses in railway engineering. It seems impracticable for the subcommittee to attempt to outline the contents of a course which would be applicable to all of the colleges. Railway engineering officers do not agree how far the colleges should go in presenting detailed material. Some of them recommend that little should be included on maintenance of way since it is their belief that training in this field can only be obtained on the track. These officers generally are of the opinion that courses should include such matters as train resistance, velocity profiles, etc., in which a student would probably never receive formal instruction except in college. However, other railway engineers believe that the courses should include a fundamental treatment of maintenance of way as a basis for subsequent practical training on the track. It must also be recognized that only a brief course may be desirable in the smaller colleges whereas there may be a demand for specialized or graduate work in railway engineering in certain of the large engineering schools.

A study of the bibliography indicates that there has not been a new book published in the broad field of railway engineering for many years. In fact there is probably only one book now available which may be considered as a textbook on this subject. This book, Raymond's "Elements of Railroad Engineering," has been revised by Riggs and Sadler. A new edition has been published recently which includes a presentation of current railway engineering matters. Most of the books which have been published in recent years are devoted to specific branches, particularly maintenance of way and trackwork. Such books are excellent for young engineers in railway service but they do not serve satisfactorily for college textbooks because they contain much detailed

information in a specific field but do not cover other topics which should be included in a course in railway engineering.

Several civil engineering handbooks contain sections dealing with certain aspects of railway engineering. The Civil Engineering Handbook (McGraw-Hill) for example has a section on railway and highway engineering; the forthcoming (1948) edition will include an enlarged section on railway, highway and airport engineering.

Authoritative material available for instruction in railway engineering is found in the Railway Engineering & Maintenance Cyclopedia; the AREA Manual; and the Proceedings of the AREA, the Signal Section, AAR, and other organizations. The following descriptions are presented to indicate the character and scope of the publications and the extent to which the material is available either for reference or textbooks.

Railway Engineering & Maintenance Cyclopedia.—This publication is compiled by an editorial staff of Simmons-Boardman Publishing Corp. in cooperation with the AREA and the Signal Section, AAR; a new edition is prepared every three years. Sections are devoted to track, bridges, water service, buildings and signals. The text contains frequent reference to current specifications and practices recommended by the AREA and the Signal Section, AAR. The Cyclopedia is illustrated throughout with photographs and drawings of material and equipment and their use in modern practice. It does not contain material on such railway engineering aspects as location, grades, curves, train resistance, tonnage rating, and velocity profiles.

The Cyclopedia is an excellent source of material for instructors of railway engineering courses and may be used to advantage as a reference book for students. It would seldom serve as a textbook due to the large amount of material it contains in the specific field of maintenance. Also its size would make it impractical for use as a textbook (8 in. x 11½ in. page size, 1294 pages, weight 6½ lb.).

AREA Manual.—This authoritative manual of "recommended practice" includes definitions of terms, designs and plans, specifications, economics of construction and maintenance, and principles and practices for railway engineering. It is issued in loose-leaf form and revised following the annual convention in March. The current (1947) edition comprises a glossary, 23 chapters on different subjects and an index. Each chapter contains material, submitted by one of the committees, which has been approved by the Association for inclusion in the Manual.

In addition to a thorough treatment of principles and practices in the field of railway maintenance of way and structures, the Manual contains a great deal of material on other aspects of railway engineering. Such topics are included as the design and operation of locomotive, passenger and freight terminals; economics of location and operation, including train resistance, locomotive capacity, tonnage rating, and velocity profiles; uniform general contract forms; waterways and harbors; and others.

The Manual provides an excellent source of reference material for instruction in railway engineering. It is not, however, suitable as a textbook due to the magnitude and detailed character of the information contained. A questionnaire by one of the subcommittees indicated that it is used as reference material in a considerable number of engineering schools.

AREA Trackwork Plans and Specifications.—This portfolio is a part of the AREA Manual and is published separately in loose-leaf form for convenient use. It contains approved plans of switches, frogs, crossings and appurtenances, together with AREA specifications, definitions and terms relating to trackwork. Although this portfolio is not suitable for a textbook it furnishes complete reference material on trackwork.

AREA Proceedings and Bulletins.—Committee reports are published in bulletins during the year. These are presented for discussion at the annual convention. The Pro-

ceedings, issued in a single volume, include the committee reports, discussion and proceedings of the annual convention, reports of officers of the Association, monographs and addresses at the annual convention.

American Railway Signaling—Principles and Practices.—The Signal Section, AAR, has issued from time to time separate chapters on various phases of railway signaling. These provide an authoritative source of reference material. The individual chapters present detailed information which is of value to those engaged in the design, construction and maintenance of signal apparatus. They would be suitable for text material in a course in which particular attention was given to railway signaling. (The material in the signal section of the Railway Engineering & Maintenance Cyclopedia is more suitable for most courses in railway engineering.)

Other Publications

Other publications of railway organizations which are of value for reference material, but not as textbooks, include the annual Proceedings of the Signal Section, AAR, the Roadmasters' and Maintenance of Way Association of America, and the American Railway Bridge and Building Association. The Locomotive Cyclopedia and the Car Builders' Cyclopedia, new editions of which are published every three years, provide reference material which may be useful to an instructor giving courses in railway engineering.

Railway Age, issued weekly, and Railway Engineering & Maintenance and Railway Signaling, both monthly publications, contain articles of current interest which are useful for assigned reading by students. The Railway Gazette (London), although primarily devoted to British railways, provides an excellent coverage of railway matters throughout the world.

The bibliography includes only books which are currently available from the publishers; such books as Wellington's classic "Economic Theory of Railway Location" have therefore been omitted. Books dealing with general railway activities in which engineering topics are discussed to a limited extent are not included.

The foregoing discussion of the material available for instruction in railway engineering indicates: (1) No *new* books have been published for many years which cover the entire field of railway engineering, (2) a new edition of one of the standard books on the subject has been published recently, (3) several books have been published in recent years which cover specific branches, particularly maintenance of way and trackwork, but they are not suitable as textbooks for courses in the general field, (4) reference material is available in the Railway Engineering & Maintenance Cyclopedia, AREA Manual, Proceedings of AREA and other organizations; the information is excellent for instructors desiring to keep in touch with current railway engineering practice but the publications are not suitable as complex text material except possibly for a few specialized courses, and (5) Railway Age and its associated Railway Engineering & Maintenance and Railway Signaling are excellent sources of reference.

It is evident that a modern book on railway engineering, based on current practice as shown in such authoritative publications as the AREA Manual and Proceedings, would be a valuable contribution to the literature in this field. It is difficult, however, to forecast the extent to which such a book would be used as a text. A thorough treatise on railway engineering would doubtless be found useful in the very limited number of engineering schools which offer highly specialized courses in that subject. At the present time, such courses are usually given by men who have had considerable background in railway engineering and much use is made of AREA reference material and current articles in railway periodicals. It seems doubtful whether a book of the

character indicated would be used in colleges where only a brief treatment of the subject is given.

Bibliography

Books on Railway Engineering and Maintenance of Way

Railway Engineering & Maintenance Cyclopedia—*Simmons-Boardman* (6th ed. 1945, new ed. every 3rd year).

Elements of Railroad Engineering by Raymond, Riggs & Sadler—*Wiley* (6th ed. 1947).

Railroad Construction by Webb—*Wiley* (9th ed. 1932).

Roadway and Track by Rench—*Simmons-Boardman* (3rd ed. 1946).

Simplified Curve and Switch Work by Rench—*Simmons-Boardman* (5th ed. 1946).

Track and Turnout Engineering by Kurtz—*Simmons-Boardman* (3rd ed. 1945).

Trackwork and Railway Structures by Tratman—*Int. Corres. Schools* (1936).

Maintenance of Track by Tratman, DeGroot & Cox—*Int. Corres. Schools* (1936).

Trackwork and the Section Foreman by Tratman—*Int. Corres. Schools* (3rd ed. 1935).

The Roadmaster and his Work by Tratman—*Int. Corres. Schools* (1932).

Books on Route Surveying and Location

Route Surveys by Rubey—*Macmillan* (1st ed. 1938).

Route Surveying by Pickels & Wiley—*Wiley* (2nd ed. 1939).

Railroad Curves and Earthwork (7th ed. 1931) and Field & Office Tables (4th ed. 1931) by Allen—*McGraw-Hill.*

Field Engineering (2 vols.) by Searles & Ives—*Wiley* (21st ed. 1936).

Easement Curve and Railroad Location by DeGroot & Baker—*Int. Corres. Schools* (2nd ed. 1932).

Handbooks Containing Material on Railway Engineering

Civil Engineering Handbook (Urquhart)—Section on Railway & Highway Engineering—*McGraw-Hill* (2nd ed. 1940; 3rd ed. 1948 to include section on Railway, Highway and Airport Engineering).

American Civil Engineers' Handbook (Merriman)—Section on Surveying, Geodsey and Railroad Location—*Wiley* (5th ed. 1930).

General Engineering Handbook (O'Rourke)—Section on Route Surveying and Earthwork—*McGraw-Hill* (2nd ed. 1940).

Civil Engineer's Handbook—Section on Curves, Earthwork, Railroad Location and Trackwork—*Int. Corres. Schools* (4th ed. 1939).

Civil Engineer's Reference Book (Trautwine)—Section on Railroads; 21st ed. 1937.

Data Book for Civil Engineers (Seelye). Some material on railways in Vol. 1, Design (1945); Vol. 2, Specifications and Costs (1946); Vol. 3, Field Inspection (in preparation)—*Wiley.*

Publications of Railway Associations

AREA Manual, American Railway Engineering Association. Recommended Practice in Railway Engineering. Issued in loose-leaf form, revised annually.

AREA Portfolio of Trackwork Plans and Specifications. Part of AREA Manual, but published separately.

AREA Proceedings and Bulletins. Committee reports published in bulletins during the year. Proceedings include committee reports, discussion and Proceedings of Annual Convention.

American Railway Signaling—Principles and Practices. Signal Section, Association of American Railroads. Comprises chapters, published separately, on various phases of railway signaling.

Manual and Annual Proceedings. Signal Section, AAR.

Annual Proceedings. Roadmasters' and Maintenance of Way Association of America.

Annual Proceedings. American Railway Bridge and Building Association.

Railway Engineering & Maintenance Cyclopedia (6th ed. 1945); Locomotive Cyclopedia (12th ed. 1944); Car Builders' Cyclopedia (17th ed. 1946). Prepared by editorial staff of Simmons–Boardman in cooperation with the AREA, and Signal Section, AAR for Railway Engineering & Maintenance Cyclopedia; and with the Mechanical Division, AAR for Locomotive and Car Builders' Cyclopedia. A new edition of each book is published every three years.

Statistics of U. S. Railways (annual) and other publications of the Interstate Commerce Commission.

Transportation in America. Railroad Committee for the Study of Transportation, AAR.

Reports of divisions, sections and committees of the Association of American Railroads.

Periodicals

Railway Age, weekly, covering all phases of railway activity—*Simmons–Boardman.*

Railway Engineering and Maintenance, monthly—*Simmons–Boardman.*

Railway Signaling, monthly—*Simmons–Boardman.*

Railway Gazette (London), weekly, primarily devoted to British railways but includes considerable material on railways throughout the world.

Report of Committee 11—Records and Accounts

F. B. Baldwin, *Chairman,*
S. H. Barnhart
B. A. Bertenshaw
W. C. Bolin
H. T. Bradley
P. D. Coons
Spencer Danby
V. H. Doyle
Benjamin Elkind
J. P. Ferris
D. E. Field
C. C Haire
H. N. Halper
J. H. Hande
A. T. Hopkins
C. H. R. Howe
C. Jacoby
W. R. Kettenring
E. M. Killough
F. C. Knight
C. A. Knowles
W. M. Ludolph
D. O. Lyle
O. M. Miles
J. B. Mitchell
B. H. Moore
H. D. Barnes, *Vice-Chairman,*
R. M. Nall
A. T. Powell
H. L. Restall
C. P. Richardson
J. H. Roach
H. B. Sampson
H. A. Shinkle
D. C. Teal
J. R. Traylor
H. C. Wertenberger
Louis Wolf

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Submitted for approval and publication in the Manual are recommended additions and revisions ..... page 308

2. Bibliography on subjects pertaining to records and accounts.

   Progress report, presented as information ..... page 311

3. Office and drafting practices:

   (a) Organization; duties and nature of assignments.

   No report.

   (b) Modern mechanical drafting aids.

   Final report, submitted as information ..... page 314

4. Statistics for railway maintenance; operation and construction.

   No report.

5. Construction reports and property records; their relation to current problems.

   Progress report, presented as information ..... page 317

6. Valuation and depreciation:

   (a) Current developments in connection with regulatory bodies and courts;
   (b) ICC valuation orders and reports;
   (c) Development of depreciation data.

   Progress report on (a), presented as information ..... page 318

7. Changes in, revision, and interpretations of ICC accounting classifications.

   Progress report, presented as information ..... page 322

The Committee on Records and Accounts,
F. B. Baldwin, *Chairman.*

AREA Bulletin 471, January 1948.

Report on Assignment 1

Revision of Manual

J. B. Mitchell (chairman, subcommittee), F. B. Baldwin, W. C. Bolin, H. T. Bradley, P. D. Coons, D. E. Field, C. C. Haire, H. N. Halper, W. M. Ludolph, C. P. Richardson, J. R. Traylor.

The committee submits the following recommendations for adoption and inclusion in the Manual:

Reinstate in the Manual as page 11–124, old page 11–71 which contained data regarding sizes of sheets for engineering drawings, forms and charts.

Reinstate in the Manual as page 11–143, old page 11–77.2 which contained designation for taper, batter, cant, slope, incline and grade.

(These two pages were part of those excluded from the Manual when the Manual material was revised and rearranged in 1943.)

Insert in the Manual on a new page 11–142, the following data concerning mechanical drawing and graphical symbols:

MECHANICAL DRAWING

Arrangement of Views—Lines and Line Work—Sectional Views

For information on these subjects refer to publication of American Standards Association Z14.1—1946, and subsequent revision thereto, entitled

American Standard Drawings and Drafting Room Practice
1946

The publication includes arrangement of views, lines and line work, sectional views, screw thread representation, dimensioning, notes, trimmed sizes of drawing paper and cloth, titles and lettering.

GRAPHICAL SYMBOLS

Plumbing, Piping, Pipe Fittings and Valves, Heating and Ventilating, Duct Work, Heat-Power Apparatus, Refrigeration and Welding

For data regarding these symbols refer to publication of the American Standards Association, Z32.2—1941, and subsequent revision thereto, entitled

American Standard Graphical Symbols for Use on Drawings in Mechanical Engineering
1941

The above publications can be obtained from the American Standards Association, 70 West 45th St., New York, 17, N. Y.

Page 11–160, Add the words "Progress Profile" at the top of the chart.

Pages 11–126 and 11–127, Delete notations at bottom of pages "Agrees with ASA Z14.1—1935."

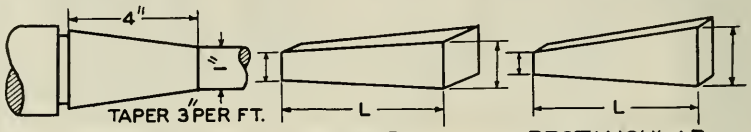
Page 11–128, Change notation at bottom of page to read: "Agrees with ASA Z14.1—1946."

SIZES OF SHEETS FOR ENGINEERING DRAWINGS, FORMS AND CHARTS

	SIZE NO.	SHAPE	A	B	C	D	E	F	G	H	J	TO BE USED FOR	REMARKS (All Dimensions In Inches)
*	1	A	11	8½	1½	¼	2¼	3¼	1			REGULAR DWGS. FORMS AND CHARTS	LENGTHEN BY MULTIPLES OF 7
	2	C	11	17		¼						FORMS AND CHARTS	FOR AREA REDUCE 11 HEIGHT TO 7
	3	B	11	8½	1½	¼	2¼	3¼	1			REGULAR DWGS. R. OF W. AND CONTRACT	TITLE MAY BE CHANGED AS INDICATED
	4	A	10½	8	1½	¼						I.C.C. APPLICATION MAP	NO TITLE BLOCK
	5	A	21	16	1½	½						DO	DO
*	6	D	17	22	1½	½	3	4½	1¼			REGULAR DRAWINGS	LENGTHEN BY MULTIPLES OF 14
*	7	D	22	34	1½	½	3	4½	1¼			DO	DO
*	8	D	34	44	1½	½	3	4½	1¼			DO	DO
	9	C	24	56		½	6	9				I.C.C. RIGHT OF WAY MAPS	
	10	A	7	4		½						CUTS FOR AREA REPORTS	REDUCTION OF SIZES - 11 - 12
	11	A	14	8		½						DETAIL DWGS. FOR AREA BULLETINS	WORKING SIZE
	12	A	21	12		½						DO	DO
	13	D	9	12½	1½	½						AREA TRACKWORK PLANS	LITHOGRAPHIC SIZE
	14	D	18	25	3	1						DO	WORKING SIZE. INCREASE B TO SUIT
	15	D	8½	17	1½	½	2½	3½	1¼			FOR STANDARD DWGS. ONLY	LITHOGRAPHIC SIZE
	16	D	17	34	3	1	5	7	2½			DO	FOR DETAILING. INCREASE B TO SUIT
*	17	D	11	17	1½	½	3	4½	1¼			REGULAR DRAWINGS	
	18												

METHOD OF DESIGNATING - TAPER - BATTER - CANT - SLOPE - INCLINE AND GRADE

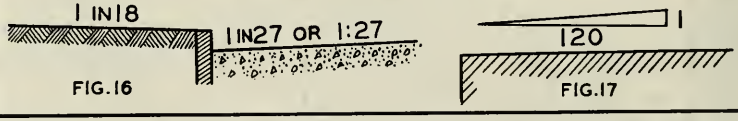
TAPER - TAPER IS THE DIFFERENCE IN DIAMETER OR WIDTH FOR A GIVEN LENGTH AND IS USUALLY EXPRESSED IN INCHES PER FOOT. STANDARD TAPERS, BROWN & SHARPE - MORSE ETC., ARE DESIGNATED BY A NUMBER WHICH FIXES THE THREE DIMENSIONS.



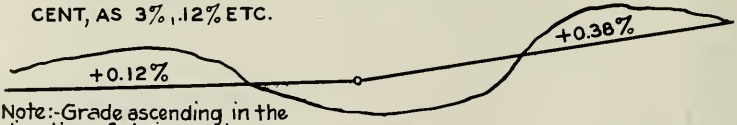
CIRCULAR FIG. 10 SQUARE FIG. 11 RECTANGULAR FIG. 12

BATTER - WHERE REFERENCE IS TO A VERTICAL DATUM, SLOPES SHOULD BE EXPRESSED AS A RATIO OF THE HORIZONTAL DISPLACEMENT TO VERTICAL DISTANCE IN WHICH ONE OF THE VALUES IS UNITY. IT MAY BE EXPRESSED IN INCHES TO THE FOOT. THE PREPOSITION "TO" SHOULD BE USED IN THIS CASE AS: 1 TO 4 ; 1½ TO 1.

SLOPE - INCLINE - CANT - WHERE REFERENCE IS TO A HORIZONTAL PLANE. SLOPE SHOULD BE EXPRESSED AS THE UNIT VERTICAL DISPLACEMENT IN CORRESPONDING HORIZONTAL DISTANCE. THE PREPOSITION "IN" SHOULD BE USED IN THIS CASE.



*GRADE OR GRADIENT - USED IN CONNECTION WITH, RAILWAYS, HIGHWAYS, SEWERS, CANALS, ETC., TO REPRESENT THE DIFFERENCE IN ELEVATION BETWEEN TWO POINTS DIVIDED BY THE DISTANCE BETWEEN THE POINTS. THIS GRADE IS GENERALLY GIVEN IN PER CENT, AS 3%, .12% ETC.



Note:-Grade ascending in the direction of chainage shown as + and decending as −.

Report on Assignment 2

Bibliography on Subjects Pertaining to Records and Accounts

V. H. Doyle (chairman, subcommittee), B. H. Moore, H. L. Restall, J. H. Roach, H. B. Sampson, D. C. Teal.

This report is submitted as information.

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Report on Assignment 3 (b)

Modern Mechanical Drafting Aids

W. M. Ludolph (chairman, subcommittee), Benjamin Elkind, D. E. Field, A. T. Hopkins, B. H. Moore, R. M. Nall, D. C. Teal.

This is a final report and is submitted as information, with the recommendation that the subject be reassigned after a number of years when new developments make another report desirable. The report describes a number of modern mechanical drafting aids which have been used in various engineering, drafting offices, not necessarily on railroads:

Maps Made From Photographs

Photogrammetry covers the science of making maps from photographs. Several methods are used, as follows:

(a) *Platting Maps from Panoramic Photographs*—The cameras used for this purpose are graduated in degrees of azimuth which are indicated on the film and in turn show in the final picture. Also, a horizontal line is shown on the photograph which is the level or elevation of the center of the camera. Graduations above and below this horizontal line indicate the vertical angle. It is quite apparent that when photographs are taken from two or more known points of the same territory, maps can be platted with considerable accuracy. This method can also be used in extended surveys similar to triangulation net works.

This method is very laborious and slow, and is therefore little used at the present time, except for mapping very inaccessible territory in mountains.

(b) *Platting Maps from Aerial Photographs*—Special cameras have been developed for this purpose, and this method depends on at least a 60 percent overlap of adjoining photographs, so that by the use of stereoscopic instruments, the photographic information can be transferred to maps. By the use of enlargers of special construction, the pictures can be made to almost any reasonable scale and also corrected for the tilt of the camera due to uneven flying and for difference of height at which the different pictures were taken.

One or more of the following instruments are used to transfer the information from the photographs to maps:

Brock stereometer
Stereocomparagraph
Photoalidade
Mechanical triangulation stereoscopes
Height finding instruments

Maps from aerial photographs are commonly made to the following contour intervals and scales:

Contour Interval	*Scale*
2 ft.	1 in. per 100 ft.
5 ft.	1 in. per 200 ft.
10 ft.	1 in. per 400 ft. or 200 ft.
20 ft.	1 in. per 1666 ft.

Local conditions and labor costs determine whether this method is economical, and proper study should be given before any project is started. This method is not economical for surveys covering small areas.

In addition to the actual aerial photographing, it will be necessary to establish a base line which will be clearly visible from the air, the length of which is known as well as the elevation of each end, so that a horizontal plane can be established for the photographs. This must be done with regular surveying equipment and it is, also, well to establish the azimuth of this line for direction control.

(c) Oblique or Angle Photographs—This method is very little used and then only when conditions are such that other methods are impossible.

(d) *Combination of the Above Methods*—Complete information in regard to this subject can be obtained from the "Manual of Photogrammetry by American Society of Photogrammetry" Pitman Publishing Company, 1944, New York and Chicago.

Reproducing Pencil Tracings

A new method of reproducing pencil tracings on tracing cloth with lines and figures of the same density as India ink lines and figures, is now being used in some drafting offices and a great deal of time is saved in inking tracings. This is a photographic process and it is essential that the pencil tracings be kept as clean as possible. On account of the great increase of contrast, spots and smudges will show as black dots, but the photographic negatives can be retouched and spotted and some of the undesirable spots removed. Tracings for standards can be made by this method, thus permitting additional information to be filled in on reproductions. This process also provides an excellent method for reproducing fine line ink tracings such as profiles.

Vapor Developed Prints

Ammonia vapor developed positive prints can now be obtained in a number of types as follows:

Black line on opaque paper
Blue line on opaque paper
Maroon line on opaque paper
Black line on opaque cloth
Black line on transparent paper
Sepia line on both sides of transparent paper
Black line on tracing cloth
Black line on plastic foil
Black line on chartfilm

Prints can be made from photographic negatives by this process on a special paper which gives a sepia image.

The advantage of this method is that no liquid touches the print and hence no shrinkage or stretching takes place and the print has the same scale as the original tracing.

Prints Developed with Special Developer

Positive prints developed by the application of a small amount of liquid developer to the surface of the paper have been obtainable for some time, and have the advantage of being very nearly the same scale as the original tracing. These are usually made on opaque paper with black lines; however, the color can be varied by changes in the developer.

Machines for Exposing Sensitized Paper

New machines have been developed to print the various kinds of prints mentioned above, as well as blue prints, the most of which depend for illumination on mercury vapor lamps and can be used in the average drafting room without the installation of any special wiring.

Microfilm

Another method of recording and reproduction makes use of the microfilm process and it is being used by the railroads, but to a greater extent in other departments, than in their drafting rooms. However, a few railroads have recorded their permanent maps and drawings on microfilm and stored the film for a permanent record in case it might be necessary to reproduce the originals.

Reconditioning Drafting Tables

Drafting table tops can be now be reconditioned by the use of plastic coverings. The drawings are fastened to these table tops by the use of adhesive tape.

Lettering Guides

Lettering guides are also playing an important part in speeding the lettering of drawings as well as improving their appearance. There are several types of these and local conditions and needs should be taken into consideration when the selection is made.

Lettering Machines

Two forms of lettering machines have been developed to type directly on drawings. With the first form, the drawing must be rolled around the roller of a long carriage

machine. In the second form, the typing mechanism works on guides which can be set to cover any part of the drawing and it is also provided with interchangeable type.

It is necessary to train the operators of these machines; however, with the newer machines, the training period is cut to a minimum due to the use of a standard typewriter keyboard and an electrically actuated stroke. Also, care must be used in selecting the ribbon to insure that sufficient pigment will be imprinted on all types of material used, particularly glazed materials so that satisfactory prints can be obtained.

With the newer machines due to better controls, the time required to set up the work in the machines has been reduced to a minimum.

Illumination

Illumination of drafting rooms is now receiving considerable attention. With the use of fluorescent lighting, considerably more light can be secured with the same amount of electricity. Also, because less heat is produced by the fluorescent lamps, higher levels of illumination can be used without discomfort to the draftsmen during warm weather and at the same time avoid eye strain due to poor illumination.

An illumination engineer should be consulted when considering an installation.

Filing Equipment

Filing equipment is also being modernized, although the basic principles are being retained and nothing sensational has been produced. In this connection, certain catalogue files deserve mention, in that the catalogues are filed in uniform binders which can be placed in a bookcase and present a net and uniform appearance.

Improved Blueprint Paper

An additional coating is now being placed on blueprint paper which increases the contrast of the image, that is, the blues are bluer and the whites are whiter.

Report on Assignment 5

Construction Reports and Property Records; Their Relation to Current Problems

W. C. Bolin (chairman, subcommittee), F. B. Baldwin, H. D. Barnes, B. A. Bertenshaw, V. H. Doyle, H. N. Halper, C. Jacoby, F. C. Knight, W. M. Ludolph, O. M. Miles, J. B. Mitchell, H. A. Shinkle, J. R. Traylor, H. C. Wertenberger, Louis Wolf.

Your committee submits the following report of progress with the recommendation that the subject be continued.

Last year this subcommittee commented on 11 current problems dependent in a large measure for their processing on construction reports and property records. These problems are still very much alive, but instead of repeating any comments this year reference is made to last year's proceedings. (See Proceedings, Vol. 48, 1947, pages 407–408.)

Your subcommittee this year has given consideration to the depreciation records as maintained under regulations of the Interstate Commerce Commission, and by the Bureau of Internal Revenue. These two requirements while similar in nature are so dissimilar in application that a dual set of records have to be maintained. Attention is called to the desirability of segregating items which are non-depreciable on the Bureau of Internal Revenue basis from items which are depreciable on both bases. If this segregation is made concurrently with the preparation of the completion report for

each AFE it can be done more economically than by having to search for concealed items buried in the details of large projects and with less likelihood of error.

Field reports on construction projects should be so prepared that distribution can be made between roadway and equipment, and operating expenses, and should distinguish between parts of a unit roused and parts retired. Electrical, mechanical and signal projects on account of their complexity, are especially hard to process where field reports are poorly prepared and incomplete.

Construction contracts should be let in such a manner that units and costs for record purposes may be available. The construction contracts should be specific that such data be furnished to the carrier.

Beyond citing these three problems, the subcommittee has not attempted to solve them either by preparing forms or prescribing methods of reporting. Each carrier should adopt such methods of reporting as will fit into its methods of handling and accounting, easily and adequately.

Report on Assignment 6 (a)

Current Developments in Connection with Regulatory Bodies and Courts

H. T. Bradley (chairman, subcommittee), H. D. Barnes, S. H. Barnhart, P. D. Coons, Spencer Danby, V. H. Doyle, H. N. Halper, J. H. Hande, C. Jacoby, E. M. Killough, F. C. Knight, C. A. Knowles, D. O. Lyle, J. B. Mitchell, B. H. Moore, H. L. Restall, J. H. Roach, H. B. Sampson.

Regulatory Bodies

The Interstate Commerce Commission appropriation for the fiscal year, beginning July 1, 1947, including $586,755 for its Bureau of Valuation, an increase of $43,075 from the $543,680 for the previous year, the increase being necessary to take care of salary adjustments. On October 1, 1947, the total force of the Bureau numbered 116 employees.

During the year 1946, Class I railroads charged to Account 459 Valuation expenses an amount of $742,230, contrasted with $729,269 for the year 1945. As of October 1, 1947, practically all Class I carriers (137) had filed 588 returns through the year 1943; 132 through the year 1944; 120 through the year 1945 and 17 through December 31, 1946. The accounting section of the bureau is now 92 percent current in its field check of these returns.

The engineering section of the Bureau of Valuation, having completed revised inventories for practically all carriers through 1932, is engaged in bringing their inventories forward to later dates, and as of October 1, 1947, was approximately 73 percent* current. The work of the accounting section in bringing summaries of original cost other than land is 94 percent* current, and original cost of land is 36 percent* current. The land section in its work of revising land valuations to current dates has completed 76 percent* of its work.

No tentative valuations as of current dates were completed and served on railroad companies, but, at the request of the Commission, the Bureau brought to date the underlying valuation estimates of carriers involved in reorganization proceedings and other cases. Opportunity is afforded the carrier to check these estimates of original

* Based on 7,500,000 mile-years from basic valuation dates through 1946.

cost, the cost of reproduction new, the cost of reproduction less depreciation, and land values, but in only a few instances have the carriers made a check of the Bureau's findings.

Most carriers have participated with the engineering section in the work of bringing their engineering reports to current dates (1910–1914 prices new and less depreciation) when their reports are reached in the Bureau's program. This affords an opportunity to check the figures and, at the same time, to secure a carbon copy of the detail pencil sheets which show the cost and depreciation elements on R.V. Form 643 upon which the information is collected.

Ex Parte No. 166. Increased Freight Rates 1947.—In this proceeding at the request of interested parties, Commissioner Aitchison placed in the record Exhibits 20 and 21 prepared by the Bureau of Valuation, which contained the Bureau's elements of value for Class I line-haul railways, estimated as of January 1, 1947. An explanation of the methods used in its derivation was included in the exhibit. The figures contained in the exhibit were shown in the aggregate for all roads and also by districts and regions. Individual carrier's figures were not listed in the exhibit although it is understood that the Bureau of Valuation is prepared to furnish individual figures upon request by the owning carrier.

No recommended final values were found by the Bureau of Valuation. In its report and decision of October 6, the Commission, under the heading of "Valuation of Railroad Properties," stated as follows:

> Certain interested parties suggested that we place in the record data concerning the value of the property in common carrier service by railroad, and our Bureau of Valuation prepared exhibits concerning the elements of the value of the property of the Class I line-haul railroads, stating the "three costs" and other factors stated in Section 19a of the act, as of the beginning of the present calendar year. The Bureau's exhibits were received in evidence without objection. For all districts the following figures were stated:
>
> | | |
> |---|---|
> | Cost of reproduction new, lands and rights, not included | $32,613,665,594 |
> | Cost of reproduction less depreciation, and rights not included | 20,653,629,888 |
> | Original cost, except lands and rights | 24,035,180,653 |
> | Present value of lands and rights | 1,935,063,167 |
> | Working capital, including materials and supplies | 610,712,400 |
>
> By the petitioners' statement, the amount of depreciation and amortization accrued by the Class I railroads as of December 31, 1946, was $5,958,242,632. Deducting this amount from the original cost item above shown, and adding the present value of lands and rights and allowance for working capital, including materials and supplies, gives $20,622,713,588 as a resulting estimate which follows methods often employed.
>
> The "Investment in railway property used in common carrier service, after accrued depreciation" claimed by the petitioners as of the same date is $22,548,-967,331. Part of the difference is due to the amounts included for cash and materials and supplies, and in part to the fact the Bureau's figures as to original cost are partly actual costs and partly estimates, and the land figures are estimates of present value, while the petitioners state the amounts carried on their books. The figure used by the state commissions is $19,591,000,000, derived by adjusting a former estimate of the Commission for subsequent changes in property.
>
> These figures are all much closer together than is usually the case when the aggregate value of railway property is involved, and for present purposes we do

not think it necessary to analyze them further, or to divide them by districts and regions.

It will be noted that the report carefully omits any reference to finding approximate aggregate value for all roads but terms the rate base found "a resulting estimate." The use of the method described in the determination of the rate base found is a radical departure from any previous finding of the Commission in a rate case where the Bureau of Valuation elements were a part of the record. The Bureau's estimate of reproduction cost apparently has been given no weight in the Commission's finding.

In commenting on the Commission's findings of "value" carriers presented testimony at the Chicago hearing, and submitted Exhibit No. 39 to show the Commission's estimate was too low. If methods employed in Ex Parte 115 in 1938 had been used the resulting total would have been $21,380,000,000 and an application of the same method, modified to the extent of deducting from original cost only recorded depreciation and amortization, would have produced $22,325,000,000. On sheet 5 of Exhibit No. 39 was shown an application of the Commission's Ex Parte 166 formula to elements of value stated in prior rate cases back to 1929. The results thus obtained were all higher than values found by the Commission at comparable dates, except for 1947 when the reverse was true. The trend of values produced by this method from 1929 on was progressively downward and apparently will continue in that direction. In commenting on the theory of using original cost as a measure of value the testimony showed that the purchasing power of the railroad construction dollar was only 40 cents in 1947 compared to 100 cents in 1914. More than 50 percent of the physical property, other than land, now owned by railroads was constructed prior to basic valuation dates (average 1916). The present value of lands and rights found by the Bureau of Valuation as of January 1, 1947, $1,935,000,000 was $800,000,000 less than that found in 1932. The Commission was asked to review its present method for determining working capital, wherein little or no allowance is made for cash.

Court Decisions

On June 25, 1947, the Supreme Court of Ohio handed down a decision in the City of Marietta v. Public Utility Commission et. al, affirming a rate order of the Utility Commission which sustained a petition of the River Gas Company and raised the prevailing Marietta domestic gas rate from approximately 42 cents per M cu. ft. to 52.2 cents based on an investigation and finding of 6½ percent return on a valuation of some $889,240, founded on current reproduction cost new less observed depreciation for property other than land, in accordance with the Ohio statute.

River Gas Company, a West Virginia corporation which operates only in Ohio, was one of a group of Standard Oil Company of New Jersey properties embracing the Hope Natural Gas Company, the Hope Construction and Refining Co. and the East Ohio Gas Co. Following the Federal Holding Co. Act of 1935, Standard Oil of New Jersey severed its connection with the four companies. The Hope Construction Company was dissolved and its properties acquired by River Company for $82,527.53. When the properties of Hope Construction were taken over by River Company, the books of Hope Construction showed that on assets of $763,000 there was an accumulated depreciation reserve of $685,000. River purchases its gas from Hope Natural Gas Co. for 35½ per M cu. ft., a price fixed by the Federal Power Commission.

Objections to the Public Utility Commission's preliminary report and finding were filed by the City of Marietta and the Office of Price Administration. Marietta complained that the valuation of the rate base is excessive, unjust and unlawful; that the exclusive use by the Commission of the reproduction cost new less depreciation method in arriving

at such valuation is unjust and unlawful; that the allowance by the Commission of a 6.5 percent rate of return on the rate base so found is also unjust and unlawful.

After a full hearing, the Commission finally approved its preliminary report and fixed the average rate for domestic gas at 52.2 cents. Marietta appealed from the Commission's order to the State Supreme Court which sustained the Commission's order, commenting that the real basis of Marietta's complaint seems to be that the Commission in its finding failed to give due consideration and especial weight to the purchase price of $82,527.53 for which River County obtained their property. The Court cited numerous U. S. Supreme Court decisions in support of its opinion, stating that it is a well-settled rule that a court will not substitute its judgment as to the value of public utility property or as to the cost of production and distribution of public utility service for the finding of the Commission on these matters and will not reverse the order of the Commission thereon unless there is a clear showing that it has abused its discretion or has omitted to give just consideration to some element in the determination of the rate-base structure or the rate of return which makes its finding unlawful and unreasonable. Continuing, the Court cited the U. S. Supreme Court decision in the case of Federal Power Commission v. Hope Natural Gas Co. that it is not theory but the impact of the rate order which counts and if the total effect of the rate order cannot be said to be unjust and unreasonable, judicial inquiry under the Act is at an end.

In this case, in accordance with its interpretation of the U. S. Supreme Court decisions in the recent natural gas cases, the Ohio Supreme Court sustained the decision of the State Public Utility Commission based on the governing statute.

On May 22, 1947, the New York State Court of Appeals handed down a decision in Staten Island Edison Corporation v. Milo R. Maltbie, et. al. In this case, the Edison Corporation alleged that the Public Service Commission's rate order resulted in confiscation of property in violation of its constitutional right to receive a fair return upon the value of its property devoted to public use, specifically alleging the property cost, reproduction cost, reasonable value, maximum rate of return under prescribed rates and that such rates will not afford a reasonable return on such cost or value. (The N. Y. Public Service Commission's orders are based on ratemaking valuations founded on original cost less accrued depreciation.) Edison asked for an injunction against the Commission's rate order.

These allegations show returns of 3.07 percent on depreciated cost and 2.42 percent on reasonable value and the Court of Appeals held they clearly support the claim of confiscation. The Court ruled that the Utility Company may obtain a judicial determination of the value of its property for ratemaking purposes. In its decision, the Court said: "There would indeed be a very drastic limitation upon the constitutional powers of the Supreme Court of the State if it may not enjoin an unconstitutional deprivation of property because of an administrative determination of constitutional right supported by administrative findings of fact believed to be wrong upon a fair consideration of the record. The remedy by certiorari proceedings being thus limited is inadequate in the protection of constitutional right and, in view of the decisions of the Supreme Court of the United States, is lacking in due process. Under these circumstances the Supreme Court of New York as a constitutional court may entertain an action for an injunction, the statutory remedy by certiorari being inadequate" * * * "We find nothing inconsistent with such a practice in the oil and gas proration cases" (here follows citations of various cases and among others, the "Federal Power Commission v. Hope Natural Gas Co., 320 U. S. 591."

The importance of this decision lies in the fact that the Public Service Commission believed that its orders were reviewable only through so-called certiorari proceedings in

which the determination of the Commission upon any question of fact is not open to review. In such cases the Courts are bound to accept the findings of the Commission if they are supported by substantial evidence. However, the Appeals Court ruled that all of the facts such as rate of return, etc., are subject to judicial review. This important decision in the field of administrative law may be appealed by the Public Service Commission to the U. S. Supreme Court.

Report on Assignment 7

Changes In, Revisions, and Interpretations of ICC Accounting Classifications

H. D. Barnes (chairman, subcommittee), S. H. Barnhart, J. H. Hande, W. R. Kettenring, C. A. Knowles, H. C. Wertenberger.

This is a progress report presented as information.

The Interstate Commerce Commission has issued the following orders of interest to engineers since this committee's last report (Proceedings, Vol. 47, 1946, page 271).

Order dated December 4, 1946, effective January 1, 1947, specifying the accounting for retirement of leased property, depreciation of jointly used property and the transfer of depreciation reserves in the case of acquisitions, mergers and reorganizations.

Order dated December 4, 1946, effective January 1, 1947, providing a condensed classification of operating expense accounts for use by Class II and Class III carriers, to be incorporated in the Uniform System of Accounts for Steam Railroads.

Order dated August 4, 1947, effective January 1, 1948, amending the Uniform System of Accounts to provide, among other things, for the operation of stockyard companies, and to provide for charging the cost of post driving and pressure grouting to Operating Expense Account 202, Roadway maintenance.

Order dated October 20, 1947, effective January 1, 1948, modifying cases 33, 40, 77, 79, 94, 118, 147, 152, 154, 171, 213, 240, 256, 271 and 290, and cancelling cases 34, 78, 89, 102, 103, 109, 153 and 259 in Accounting Bulletin No. 15 for Steam Railroads.

The ICC, in Docket No. 29140, decided February 10, 1947, found that expenditures for labor and material in driving posts and for pressure grouting to arrest water pockets and mud heaves, were properly chargeable to operating expenses.

In addition to these orders the Bureau of Accounts released the following new rulings:

Issued July 1, 1947—

Case A–182. Prescribes the accounting for the cost of the first installation of furniture and office equipment and for subsequent additions and renewals.

Issued October 15, 1947—

Case A–183. Provides that the cost of "Sperry Rail Service" be charged to Operating Expenses, Account 220, Track laying and surfacing.

Case A–184. Prescribes the accounting for rental payments by The Pullman Company for the use of railway owned sleeping cars.

The Bureau of Accounts also issued Accounting Series Circular No. 99 which requires Class I line-haul carriers and lessors to and proprietary companies of such railways, to distribute to appropriate primary accounts prior to December 31, 1947, amounts reported as "unassigned" in schedule 211 of the annual report form A to the ICC.

Report of Committee 5—Track

E. W. Caruthers, *Chairman,*
Lem Adams
L. L. Adams
J. C. Aker
C. A. Anderson
W. G. Arn
A. L. Bartlett
T. H. Beebe
J. A. Blalock
Blair Blowers
H. J. Bogardus
A. E. Botts
W. S. Boyce
C. W. Breed
E. J. Brown
M. D. Carothers
H. R. Clarke
R. W. Claypoole
W. E. Cornell
E. D. Cowlin
B. E. Crumpler
H. Q. Day
L. W. Deslauriers
M. H. Dick
J. A. Ellis
J. E. Fanning
H. F. Fifield
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C. E. R. Haight
B. F. Handloser
H. H. Harman
A. B. Hillman
J. P. Hiltz
A. F. Huber
W. G. Hulbert
C. T. Jackson
T. R. Klingel
J. de N. Macomb
G. M. Magee
E. E. Martin
L. I. Martin
F. J. Bishop, *Vice-Chairman,*
F. H. Masters
R. W. Mauer
J. S. McBride
R. E. Miller
J. B. Myers
G. A. Peabody
J. A. Reed
O. C. Rehfuss
L. H. Roden*
M. K. Ruppert
R. E. Sampson
I. H. Schram
G. J. Slibeck
R. R. Smith
C. R. Strattman
Troy West
R. P. Winton
M. J. Zeeman

Committee

* Died July 2, 1947.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including recommended reapproval of Manual material .... page 325

2. Fastenings for continuous welded rail, collaborating with Committee 4.

   Progress report, presented as information ..... page 325

3. Plans and specifications for track tools including their repair and reclamation, with recommended minimum limits for reclaimed tools, collaborating with Committees 1 and 22 and with Purchases and Stores Division, AAR.

   No report.

4. Plans for switches, frogs, crossings, spring and slip switches, collaborating with Signal Section, AAR.

   Progress report presented as information and recommended revisions of plans and specifications ..... page 327

   Appendix 4-a, a study of the guarding of center frogs in small angle crossings ..... page 328

   Appendix 4-b, progress report on performance of solid manganese crossing frogs and special frog support ..... page 334

   Appendix 4–c, progress report on fatigue tests of manganese steel ..... page 336

AREA Bulletin 472, February 1948.

5. Prevention of damage due to brine drippings on track and structures, collaborating with Mechanical Division, AAR.

   No report.

6. Design of and stresses in tie plates, collaborating with Committees 3 and 4.

   Recommended revision of specifications, and plans in substitution of those now appearing in the Manual ..... page 337

7. Hold-down fastenings for tie plates; design, use and economy with respect to minimizing tie wear, collaborating with Committee 3.

   Progress report, presented as information ..... page 357

8. Effect of lubrication in preventing frozen rail joints.

   No report.

9. Recommendations on number and placing of anti-creepers for various conditions.

   Progress report on the result of test installations which is submitted as information and recommendations for the placing of rail anchors to be substituted in the Manual for the information now appearing therein pertaining to rail anchorage ..... page 362

THE COMMITTEE ON TRACK,
E. W. CARUTHERS, *Chairman.*

Littleton Hewitt Roden

Littleton Hewitt Roden, who died on July 2, 1947, was born at Richmond, Va., December 26, 1901. He received his education in the public schools of Richmond, and the Virginia Polytechnic Institute, from which he was graduated in 1922 with a degree in Mining Engineering.

From 1922 until 1927, he was engaged in mining engineering work. In June 1927, he entered the service of the Chesapeake & Ohio Railway, and at the time of his death was assistant engineer in the engineering department.

Mr. Roden became a member of the American Railway Engineering Association in 1938. He had been a member of Committee 5-Track since 1944 and a member of Committee 1-Roadway and Ballast since 1939, serving as vice-chairman of the latter committee from 1945 until his decease.

The members of the Track committee here record their appreciation of his conscientious and helpful service, and their deep regret at his untimely passing.

Report on Assignment 1

Revision of Manual

C. R. Strattman (chairman, subcommittee), C. A. Anderson, W. G. Arn, T. H. Beebe, J. A. Blalock, M. D. Carothers, C. T. Jackson, R. E. Sampson, R. R. Smith, M. J. Zeeman.

Your committee offers for reapproval without change, the following text now appearing in the Manual.

Pages 5–15 and 5–16

Specifications for Soft Steel Cut Track Spikes

Page 5–17

Design of Cut Track Spikes

Page 5–18

Table of Temperature Expansion for Laying Rail

Page 5–19

Oiling Track Fixtures

Pages 5–44 and 5–45

Vertical Curves

Report on Assignment 2

Fastenings for Continuous Welded Rail

Collaborating with Committee 4

A. L. Bartlett (chairman, subcommittee), Lem Adams, F. J. Bishop, W. S. Boyce, E. W. Caruthers, R. W. Claypoole, M. H. Dick, J. E. Fanning, H. F. Fifield, C. E. R. Haight, H. H. Harman, J. de N. Macomb, G. M. Magee, E. E. Martin, F. H. Masters, J. S. McBride, J. A. Reed, R. R. Smith, C. R. Strattman.

Your committee submits the following report of progress:

During August 1947 the test track at New Haven was connected with an adjacent yard track and is now used as an outbound departure track. The daily gross tonnage, about 10,000 tons, is all slow freight, 80 percent being in one direction. Observation is being continued.

The results from observation of action of 1200 ft. of 131-lb. continuous rail test track are as follows:

1. Change in length of one rail resting freely on tie plates with 92 deg. temperature range, 0.717 ft., approximating the theoretical change.
2. Change in length of one rail, 2 spikes per tie per rail, with 92 deg. temperature range, 0.452 ft.
3. Change in length of one rail, 16 compression clips first 5 end rails, 12 clips intermediate rails, 70 deg. temperature range, 0.12 ft. and 0.13 ft., total 0.25 ft.
4. Change in length of one rail, 8 ties boxed with anti-creepers first 5 end rails, 4 ties boxed intermediate rails, 70 deg. temperature range, 0.125 ft. and 0.135 ft., total 0.26 ft.

One-inch stone ballast was used, and movement possibly could have been decreased materially if graded ballast had been used. The cribs have been filled with ¾-in. to 1½-in. graded stone ballast for future tests.

It is quite apparent that both ends of each continuous rail should be fully anchored to minimize the gap at each end. The required anchorage may be computed as follows:

Stress in rail restrained against movement due to temperature change—

$$S = nEta$$

Where S = Stress in rail
n = Coefficient of expansion, 0.0000065
E = Modulus of elasticity, 30,000,000
t = Temperature range
a = Area of rail in square inches

Therefore, $S = 195ta$

Number of ties on each rail to be anchored, $N = \frac{S}{r}$

Where r equals tie resistance in the ballast.

Therefore, $N = \frac{195ta}{r}$

It will be noted that joint restraint has not been considered. Without question joint restraint usually is a definite and considerable restraining force. However. its magnitude is difficult of determination without special apparatus and is not constant through continued service. With these facts in mind it would seem advisable to anchor the rail completely to compensate for total computed stress, the joint restraint to be used as an indefinite factor of safety. It should be understood that with any amount of anchorage there will be some movement at the ends of welded rail, which condition is covered in report of this committee in the Proceedings, Vol. 38, 1937, pages 494 to 498. Here joint restraint is of definite value in maintaining the joint gap within practical limits.

As to the value of r, tie resistance, there seems little reliable data, particularly with respect to various types of ballast. Apparently the value generally accepted lies between 500 lb. and 800 lb. per tie, per rail. Tests recently made on the New York, New Haven & Hartford on a 5-tie panel, 131-lb. rail, 1-in. stone ballast developed an initial movement at 1050 lb. per tie per rail. In main line track, well ballasted with 2-in. stone, the initial movement began at 1200 lb. to 1400 lb. These tests were made using an hydraulic jack with the pressure gage. Further tests will be made with a device using the lever principle with small weights, which should provide more accurate results. Both gravel and stone ballasted track will be tested.

Relative to the temperature range, it may be well to consider the fact that in portions of the country where ballast freezes during the winter, tie resistance is at least doubled, and in territory where freezing does not occur temperature ranges are not excessive. With these facts in mind it would seem unnecessary to use a range in excess of 70 deg. or from +10 deg. to +80 deg.

As to intermediate anchorage, the amount will depend on the gap which one is willing to permit in case of a break. Obviously the minimum gap will result with all ties anchored. On one railroad where M & L plates are used with spring clips on both sides of each rail on each tie, with one exception, out of 15 reported breaks in continuous rail from 590 ft. to 7393 ft. long the maximum gap was 2¾ in. with temperature ranges from 58 deg. to 98 deg. The exception was a rail 2000 ft. in length where the gap was 6½ in. This was alleged to be due to severe grade condition.

Should jointed rail be used adjoining welded rail, it should be anchored at the end similarly to the welded rail, to minimize the push or drag on the latter. With this accomplished the conventional joint bar, either 4 or 6-hole should give satisfactory service, the same being true for insulated joints, whether in welded rail sections or between welded and jointed rail.

Inspection of continuous rail installations where various types of fastenings are used, including the GEO plate, M&L plate, and the conventional double-shoulder plate with cut spikes, together with information based on experience of those responsible for maintenance of the rail, indicates that all are suitable for continuous rail. However, so far as the conventional plate and cut spikes are concerned, very few installations are equipped with this type of fastening where there is high speed passenger and freight traffic. Information in connection with one installation of this type carrying fast trains has just been received by the committee and will be studied promptly.

Additional study of the effect of traffic on continuous rail would seem desirable, and should include one and two-way traffic, although practical experience would seem to indicate that this feature is of minor importance except on heavy grades.

Study of this problem is being continued with a view of making conclusive recommendations at the earliest possible date.

Report on Assignment 4

Plans for Switches, Frogs, Crossings, Spring and Slip Switches, Collaborating with Signal Section, AAR

F. J. Bishop (chairman, subcommittee), L. L. Adams, J. C. Aker, C. A. Anderson, W. G. Arn, T. H. Beebe, J. A. Blalock, C. W. Breed, E. D. Cowlin, H. Q. Day, L. W. Deslauriers, J. A. Ellis, J. W. Fulmer, A. B. Hillman, A. F. Huber, W. G. Hulbert, C. T. Jackson, T. R. Klingel, G. M. Magee, L. I. Martin, F. H. Masters, R. E. Miller, J. B. Myers, G. A. Peabody, J. A. Reed, O. C. Rehfuss, L. H. Roden, I. H. Schram, G. J. Slibeck, C. R. Strattman, R. P. Winton, M. J. Zeeman.

Your committee offers the following recommendations:

Add to Appendix "A," Article 4 (Manganese Steel Track Castings), Paragraph 408, Portfolio of Trackwork Plans, the following paragraph:

> Bolt holes shall not be enlarged by cutting or reaming with an oxyacetylene torch.

Your committee further recommends:

Plan 701–40 Bolted Rail Crossings, etc
" 702–41 " " " "
" 703–41 " " " "
" 704–41 " " " "
" 782–47 Articulated Manganese Steel Crossings.
" 783–47 " " " "

be revised by changing note 2 (d) on each of the above plans to read as follows:

> 2 (d) Corner Braces—shall be of forged steel or of cast steel, grade N–1, annealed, machined to fit closely into fishing space of the rail, and into the fillets of rail for not less than ½" below the head and above the base flange.

The Standardization Committee of the Manganese Track Society collaborated with your committee on the preparation of the above recommendations.

Appendix 4–a

A Study of Guarding of the Center Frogs in Small Angle Crossings

By G. M. Magee
Research Engineer, Engineering Division, AAR

Where rigid frogs are used in crossings of small intersection angles, the wheel can only be held away from the facing frog point by the back of the mating wheel contacting the inner face of the flangeway of the opposite frog. This condition for tangent track is shown in Fig. 1, which also shows that when the intersection angle is 17 deg., 26 min., or more, the wheel will be perfectly guarded at the facing frog point (A) by the mating wheel contact in the opposite flangeway at point (B).

It is obvious, however, that a length along the flange of the wheel can be depended upon for guarding the point so that angles smaller than 17 deg., 26 min., may be safely used. This is illustrated in Fig. 2, which shows that the intersection angle Δ of the crossing which will be guarded will depend upon the guarding length of the wheel flange (F). The angle Δ may be determined for any length of F by the formulas shown in Fig. 2.

The guarding length of the wheel flange that may be depended upon is thus the important determining factor. To guard a wheel properly, the wheel must not only slip itself at the guarding point, but must develop sufficient additional lateral force to slip its mating wheel. This is illustrated in Fig. 3. The angle β represents the angle of contact of the wheel flange with the frog flangeway at the point where a guarding force is developed.

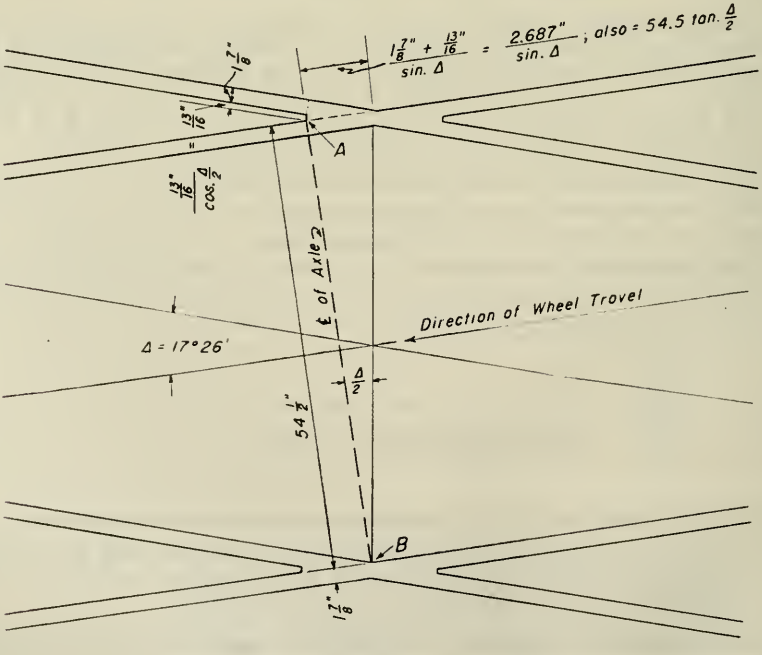


Fig. 1.

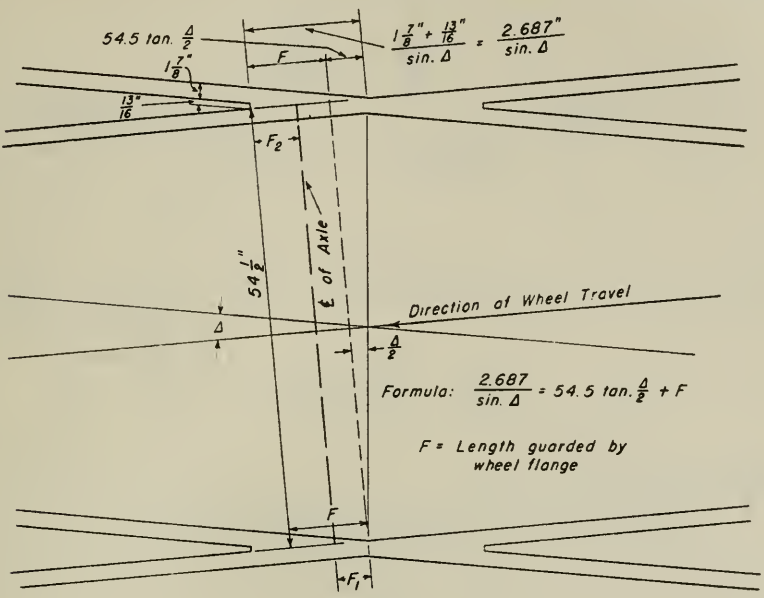


Fig. 2.

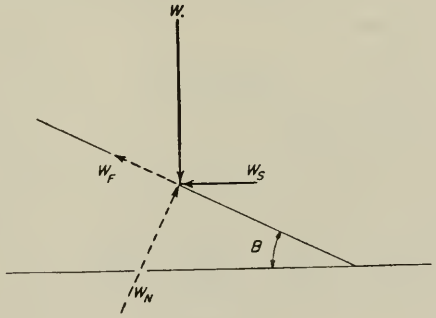


Fig. 3.

W represents the load on the guarding wheel, and W_S is the lateral force required to slip the mating wheel. W_N is the reaction normal to the flangeway and W_F is the frictional component of the reaction parallel to the flangeway.

Then the known forces are W (the wheel load) and α (coefficient of friction).

Therefore $W_S = W\alpha$ and ..... (1)

$W_F = W_N\alpha$ ..... (2)

Σ of vertical forces:

$W - W_N \cos\beta - W_F \sin\beta = 0$ ..... (3)

Σ of horizontal forces

$W_S + W_F \cos\beta - W_N \sin\beta = 0$ ..... (4)

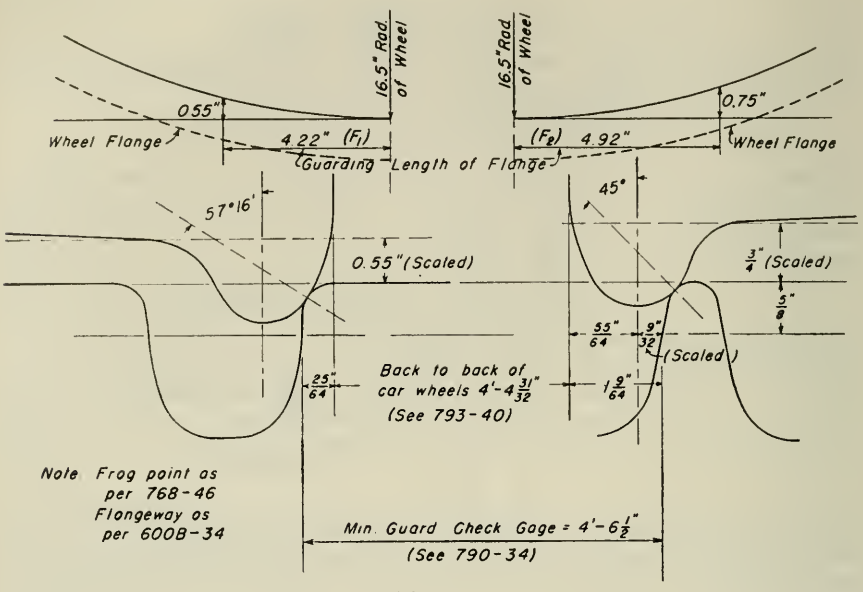


Fig. 4.

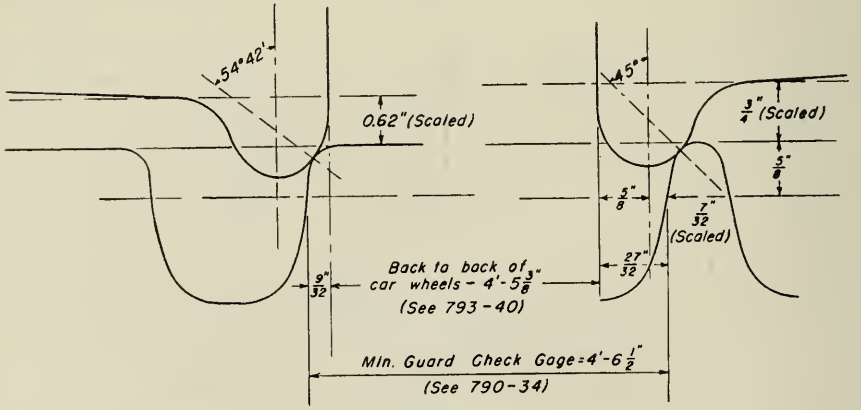


Fig. 5.

The unknown terms are therefore W_N and β.
By substitution in equation (3):

$$W\alpha + W_N \alpha \cos\beta - W_N \sin\beta = 0$$

$$\text{or } W_N = \frac{W}{(\cos\beta + \alpha\sin\beta)} \quad \ldots\ldots (5)$$

By substitution in equation (4):

$$W\alpha + W_N \alpha \cos\beta - W_N \sin\beta = 0$$

$$W_N = \frac{-W\alpha}{(\alpha\cos\beta - \sin\beta)} \quad \ldots\ldots (6)$$

Equating values of W_N in (5) and (6):

$$\frac{W}{(\cos\beta + \alpha\sin\beta)} = \frac{-W\alpha}{(\alpha\cos\beta - \sin\beta)}$$

Then $\alpha\cos\beta - \sin\beta = -\alpha\cos\beta - \alpha^2\sin\beta$

$2\alpha\cos\beta + \alpha^2\sin\beta - \sin\beta = 0$

$2\alpha\cos\beta + (\alpha^2 - 1)\ \sin\beta = 0$

dividing by $\cos\beta$

$2\alpha + (\alpha^2 - 1)\ \tan\beta = 0$

$$\tan\beta = \frac{2\alpha}{(1 - \alpha^2)} \qquad (7)$$

By assuming different values for the coefficient of friction α the following values for β are obtained:

α	β
0.25	29 deg.
0.33	37 deg.
0.50	53 deg.

The coefficient of wheel slippage on a rail is ordinarily taken at 0.25 in locomotive design, which would require an angle β of 29 deg. However, to provide a reasonable factor of safety an angle for β of at least 45 deg. seems desirable.

In Fig. 4, at the right hand side, the wheel contour (for one-wear wrought and cast steel wheels and cast iron wheels) is shown with reference to the point of frog, the angle of contact being 45 deg., which will insure slipping the wheels to the left into proper position as the wheel rolls ahead. This position of the wheel is the farthest to the right that it can assume without danger of splitting or damaging the frog point. The mating wheel on the axle must therefore be in a guarding position to insure that no farther movement can occur.

The position of the mating wheel is shown at the left of Fig. 4. In arriving at the position of this wheel, the minimum guard check gage of 4 ft. 6½ in. (corresponding to a track gage of 4 ft. 8⅜ in.) must be used, as obviously the narrowest track gage permissible offers the greatest likelihood of splitting the frog point. The position of the mating wheel is then determined by the wheel gage and since the contact angle so obtained is greater than 45 deg., this position may be depended upon for guarding. The guarding length of the wheel flange (or dimension F) is then determined, as shown at the top of Fig. 4, by computing the distance from a vertical center line through the wheel to the point where the tread is in the position relative to the flangeway contour as shown at the right and left of Fig. 4. The guarded length for this condition is 9.14 in.

In Fig. 5, a similar drawing is made for multiple and two-wear wrought steel and cast steel wheels. Since the 0.62-in. dimension is greater than the corresponding 0.55-in. dimension in Fig. 4, it is obvious that the guarded length for these wheels is slightly greater than for the cast iron wheel. Accordingly, only the conditions for the cast iron wheel need be considered as these will be determining.

If the wing or guard portion of the frog is raised 1 in., this will, of course, increase the guarding length of the wheel flange. Fig. 6 illustrates this condition. In showing the flangeway contour with the raised wing rail, the side of the flangeway has been formed by extending the 3/32 in. in 1 in. slope. There is no definite recommendation on this in the AREA trackwork plans, although this side appears to be vertical in the plans shown. It does not seem practical to maintain this as a vertical face; also, it

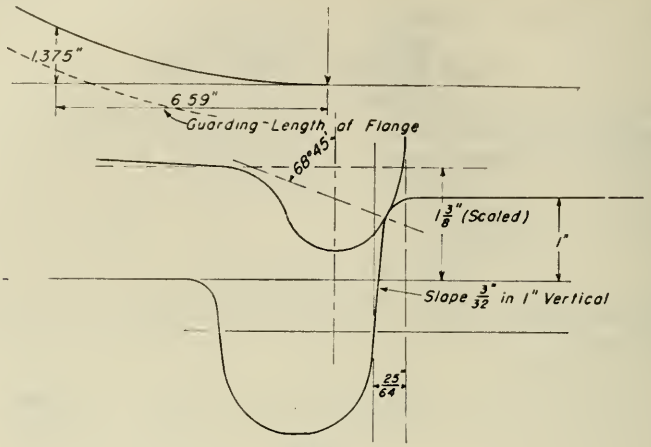


Fig. 6.

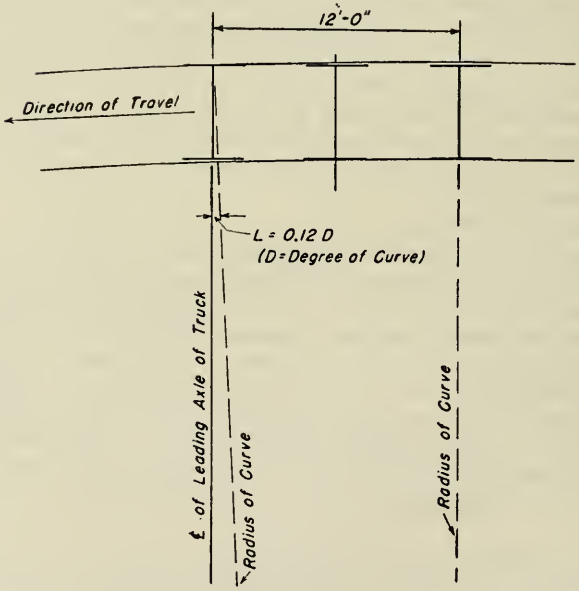
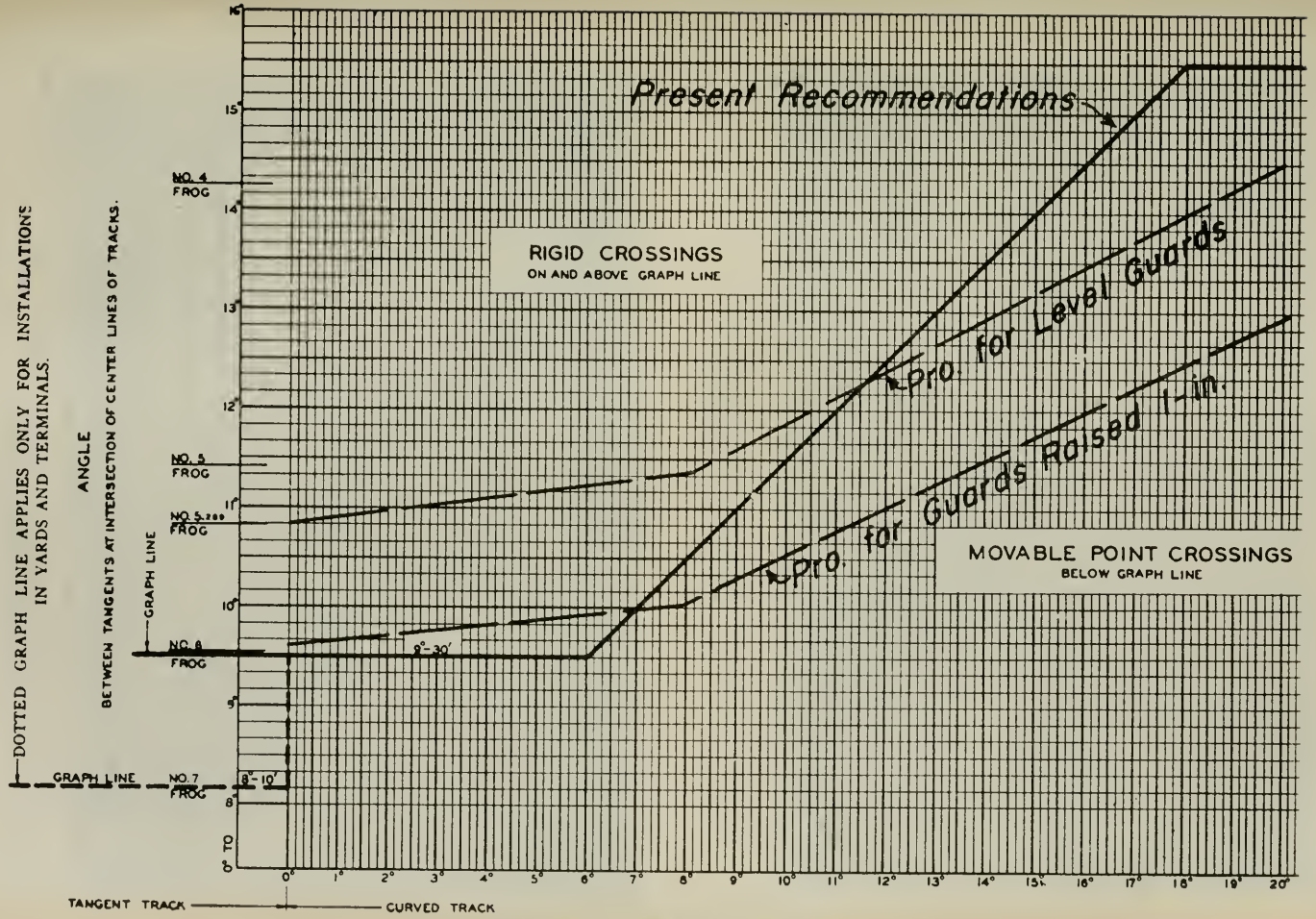


Fig. 7.

would not take the "Frog and Crossing Limit Gage," Plan 790–34. Accordingly, the above mentioned slope has been used. For this condition and 4 ft. 8⅜-in. track gage, the guarding length of the wheel flange is increased to 11.51 in.

On curved track, the amount of curvature even up to 20 deg. is not enough to change appreciably the method of solution of the triangle by the equation $2.687 \div \sin \triangle$. However, with sharp curvature requiring widened gage, the 2.687 in. term representing the width of flangeway plus the width of frog point will have to be increased to include



Reproduction of Trackwork Plan 820–46.

the widened flangeway. Also the angle that the leading axle of a truck assumes in traversing a curve must be taken into account. Observations have shown that the trailing axle of a truck tends to aline itself radially, as illustrated in Fig. 7. Thus the angle $\triangle/2$ shown in Fig. 2 will be reduced by the length of the wheel base (taken as 12 ft. as a maximum value) times the degree of curvature.

The formula for determining $\triangle$ then becomes

$$\frac{\left(\frac{13}{16}+f\right)}{\sin \triangle} = 54.5 \tan\left(\frac{\triangle}{2} - 0.12\,D\right) + F$$

in which $\triangle$ = Intersection angle of the crossing in deg.
f = Width of widest flangeway in inches.
D = Rate of maximum curvature in deg.
F = Length guarded by wheel flange in inches.

The value of $\triangle$ has been computed that will satisfy the above equation for various rates of curvature with gage widened in accordance with Series "A" of Plan No. 791–34 of the Portfolio of Trackwork Plans. These values are shown by the long dashed lines on the reproduction of Plan 820–46. It is recommended that these values be given consideration in any revision of this plan.

Appendix 4–b

Progress Report on Performance of Solid Manganese Crossing Frogs and Special Frog Support

Previous committee reports have described stress measurements made in the flangeways and at other significant stress areas of five different designs of crossing frogs for the crossing of the Baltimore & Ohio Chicago Terminal Railroad and the Atchison, Topeka & Santa Fe Railway at McCook, Ill. Upon completion of the stress measurements, a service schedule was set up under which each design is left in place for a period of one year in the test corner as shown in Fig. 1 of last year's report, Proceedings, Vol. 48, 1947, page 559. Last year's report described the observed performance of the Morden–Ramapo design and the Bethlehem design.

New Taylor–Wharton Design

The new Taylor–Wharton design, described in last year's report, was placed in service in April 1946. This casting was designed to provide an increased flexural or girder strength. After completing its one-year test service, it was removed from track on May 26, 1947. In general, the casting was in very good condition, as shown in Figs. 1 and 2. There was a slight spalling at the points which could be readily repaired by welding. Careful examination showed that small vertical cracks had started at both top and bottom fishing surfaces near gage positions 1 and 12 (See Fig. 2, page 560, Vol. 48). The measured stresses were not high at these areas. Also, a small vertical crack had started in the fillet at the top fishing surface where the 11025 rail abutted the casting. There were no perceptible flangeway cracks.

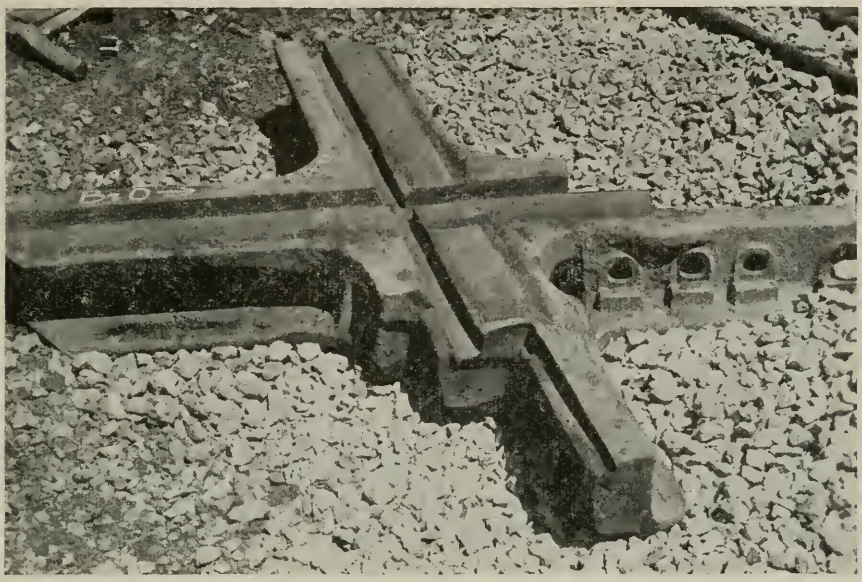


Fig. 1.—Top View of New Design of Taylor–Wharton Casting Removed after One Year of Service.

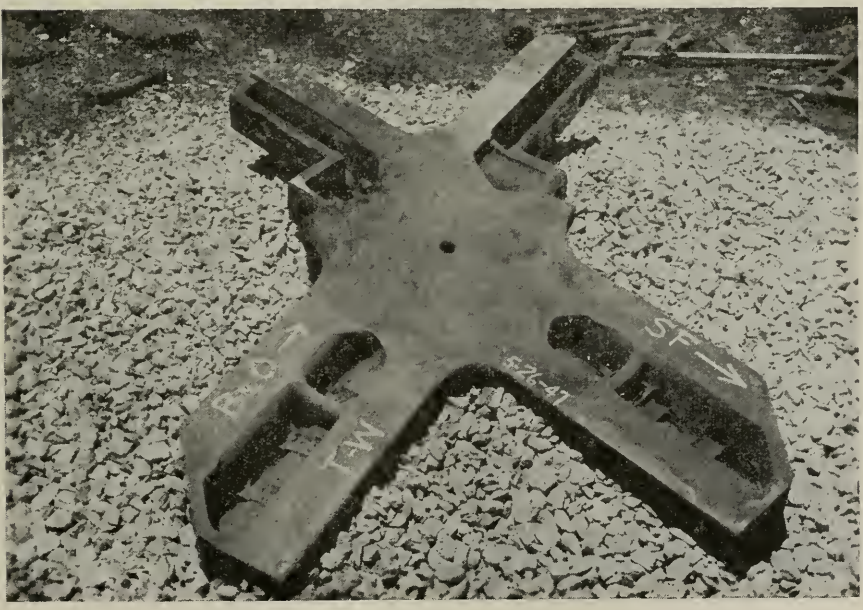


Fig. 2.—Bottom View of Casting Shown in Fig. 1.

Other Designs

The original Taylor–Wharton design was installed in the test corner May 26, 1947, and the Carnegie–Illinois design was installed in the corresponding corner position in the crossing of the Santa Fe westbound track with the B. & O. southbound track (See Proceedings, Vol. 48, 1947, Fig. 1, page 559). The service performance of these castings will be reported next year.

Installation of Special Steel Frog Support

The installation of a special integrally welded steel T-section type of frog support to relieve the crossing castings of flexural stresses was described in last year's report. This installation has been continued in service and observed periodically. The asphaltic concrete has never set up properly to give the T-section a sufficiently firm support. Both of the crossings supported on the steel T-beam sections had moved slightly in the direction of traffic. Inasmuch as there appeared to be no good way to realine them, the connecting track was lined slightly with satisfactory results. These two crossings were also raised and tamped in November 1947.

The castings are in good condition in both crossings. A longer service period will be required to determine whether the steel T-section offers any advantages over the generally used crossing timber support.

Appendix 4–c

Progress Report on Fatigue Tests of Manganese Steel

In the investigation of the causes of the development of flangeway cracks in manganese frogs, stresses were measured in actual service to determine the range of repeated stress to which the steel is subjected. Little information is available on the fatigue strength of Hadfield manganese steel for the particular fatigue range found in these measurements—a stress reversal from a high compression to a tension half as great. Accordingly, it was decided to make laboratory fatigue tests to develop this information.

Specimens have been obtained and the tests are being made at the University of Illinois by Russell Jensen, special research associate of engineering materials. The tests include three different conditions of surface finish: (1) As cast with the mill scale on, (2) ground surface, and (3) ground surface subsequently shot peened. Each of these types of surface finish could be provided in the flangeways of frogs or crossings. Specimens for each condition of surface finish are being tested under three conditions as follows: With no corroding agent, with a five percent sulfuric acid corroding agent, and with the same corroding agent applied to surfaces that have been given corrosion protection. This acid solution is undoubtedly a more severe corroding agent than is encountered in service, but has the advantage of producing accelerated results.

It is expected that the nine series of tests will be completed during 1948 and that the results will be presented in the committee report for next year.

Report on Assignment 6

Design of and Stresses in Tie Plates

Collaborating with Committees 3 and 4

J. de N. Macomb (chairman, subcommittee), C. A. Anderson, W. G. Arn, F. J. Bishop, Blair Blowers, W. S. Boyce, C. W. Breed, M. D. Carothers, E. W. Caruthers, H. R. Clarke, R. W. Claypoole, B. E. Crumpler, J. W. Fulmer, B. F. Handloser, J. P. Hiltz, C. T. Jackson, G. M. Magee, E. E. Martin, J. B. Myers, I. H. Schram, J. A. Reed, M. J. Zeeman.

This report embraces material for adoption and publication in the Manual, as substitutes for material now appearing therein, together with brief statements of explanation that are offered as information.

Specifications for Tie Plates

For the purpose of clarifying the language of the Specifications for Soft and Medium Steel Tie Plates, your committee has prepared a redraft of these specifications under the title Specifications for Low Carbon Steel Tie Plates which are offered for adoption and publication in the Manual to replace the present specifications.

For the same reason a new draft has been prepared of the Specifications for Hot-Worked, High-Carbon Steel Tie Plates, which are submitted for adoption to replace the present specifications bearing the same title. The changes in the two specifications are presented in detail on page 356.

Simplification of Tie Plates

In the report appearing in the Proceedings, Vol. 48, 1947, pages 568 to 586, incl., your committee presented a brief account of the cooperative effort initiated by the American Iron and Steel Institute, in which your committee participated, to develop designs of tie plates which would meet the requirements of the railroads and reduce the number of designs now being produced, it being the purpose to offer such designs for adoption and publication in the Manual in place of the designs now appearing therein.

Included in the 1947 report as indicating the progress made in this effort, there were presented as information plans for 15 tie plates that had been developed by the AISI. Since that time the AISI has made some alterations of these designs and added three others, and all 18 of these designs appear on the following pages.

As it is the opinion of your committee that plans 1 to 13, incl., will meet the general requirements of the railroads more adequately than the designs now in the Manual, your committee recommends the adoption of these 13 plans for publication in the Manual in substitution for the designs of tie plates now appearing on pages 5–4 to 5–8.6, incl., with the proviso that each of plans 1 to 13, incl., shall bear a note reading "size and location of spike holes to be optional with a maximum of eight." (Plans 14 to 18, incl., are for information only.)

(text continued on page 356)

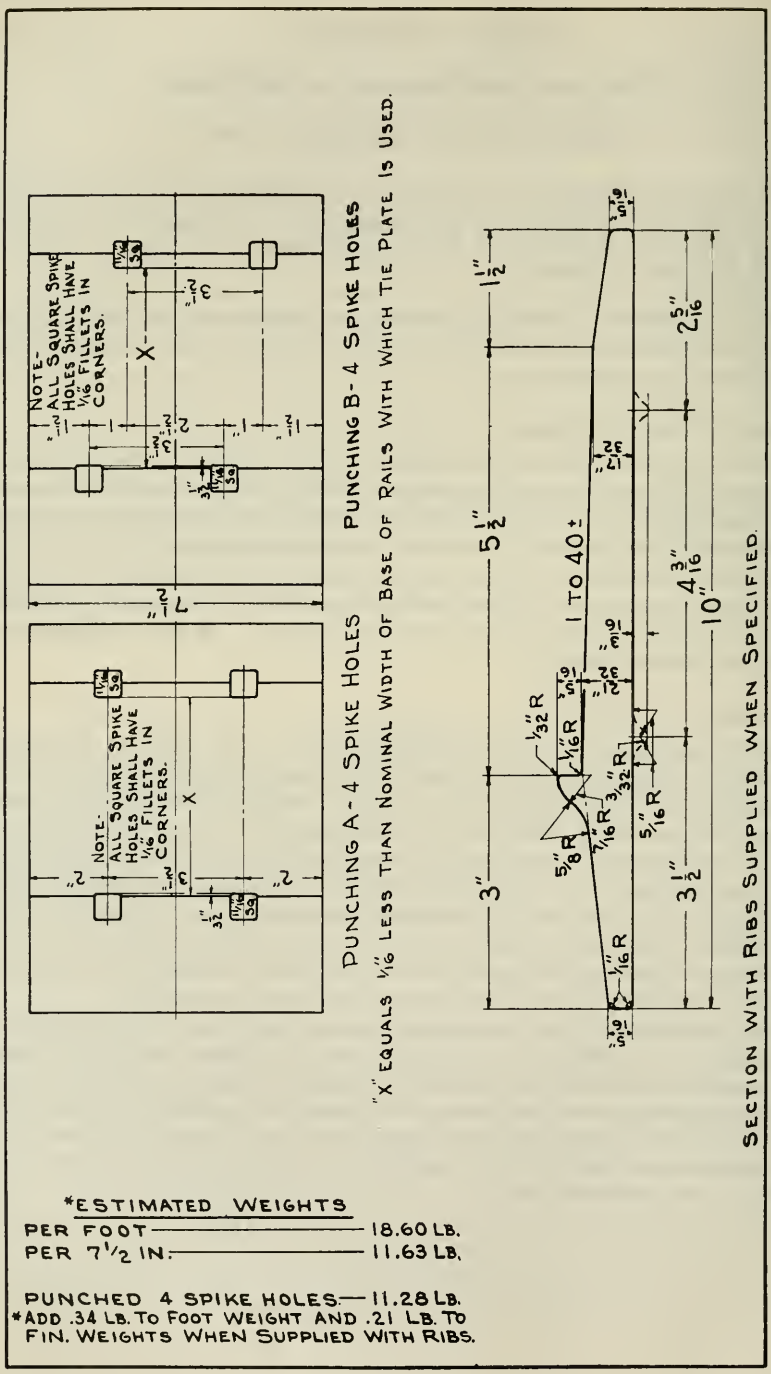
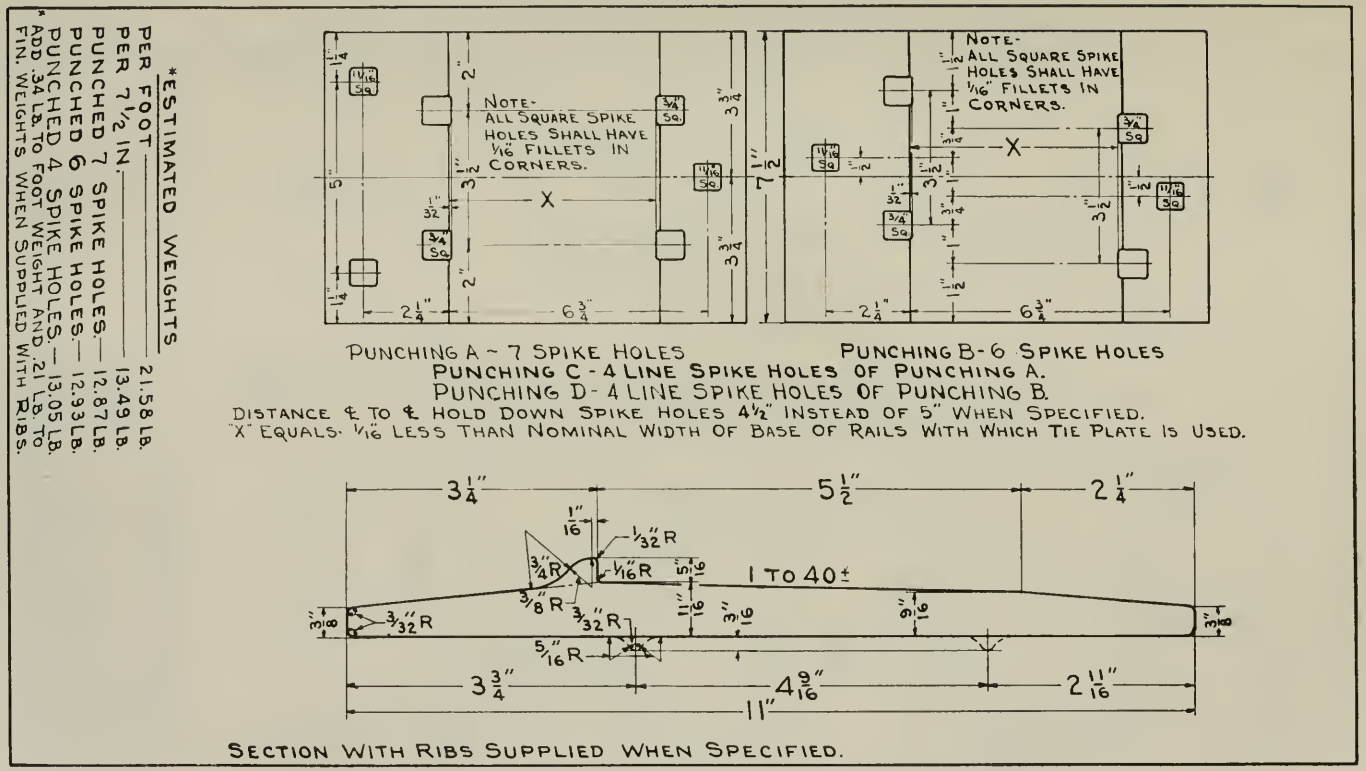

NOTE-
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16 FILLETS IN CORNERS.
PUNCHING A-4 SPIKE HOLES
PUNCHING B-4 SPIKE HOLES
"X" EQUALS 1/16 LESS THAN NOMINAL WIDTH OF BASE OF RAILS WITH WHICH TIE PLATE IS USED.
SECTION WITH RIBS SUPPLIED WHEN SPECIFIED.
1 TO 40±
*ESTIMATED WEIGHTS
PER FOOT — 18.60 LB.
PER 7 1/2 IN. — 11.63 LB.
PUNCHED 4 SPIKE HOLES — 11.28 LB.
*ADD .34 LB. TO FOOT WEIGHT AND .21 LB. TO FIN. WEIGHTS WHEN SUPPLIED WITH RIBS.

Fig. 1.—AISI 10-in. Tie Plate for Use with Rails with 5⅛-in. to 4 7/16-in. Base Width.

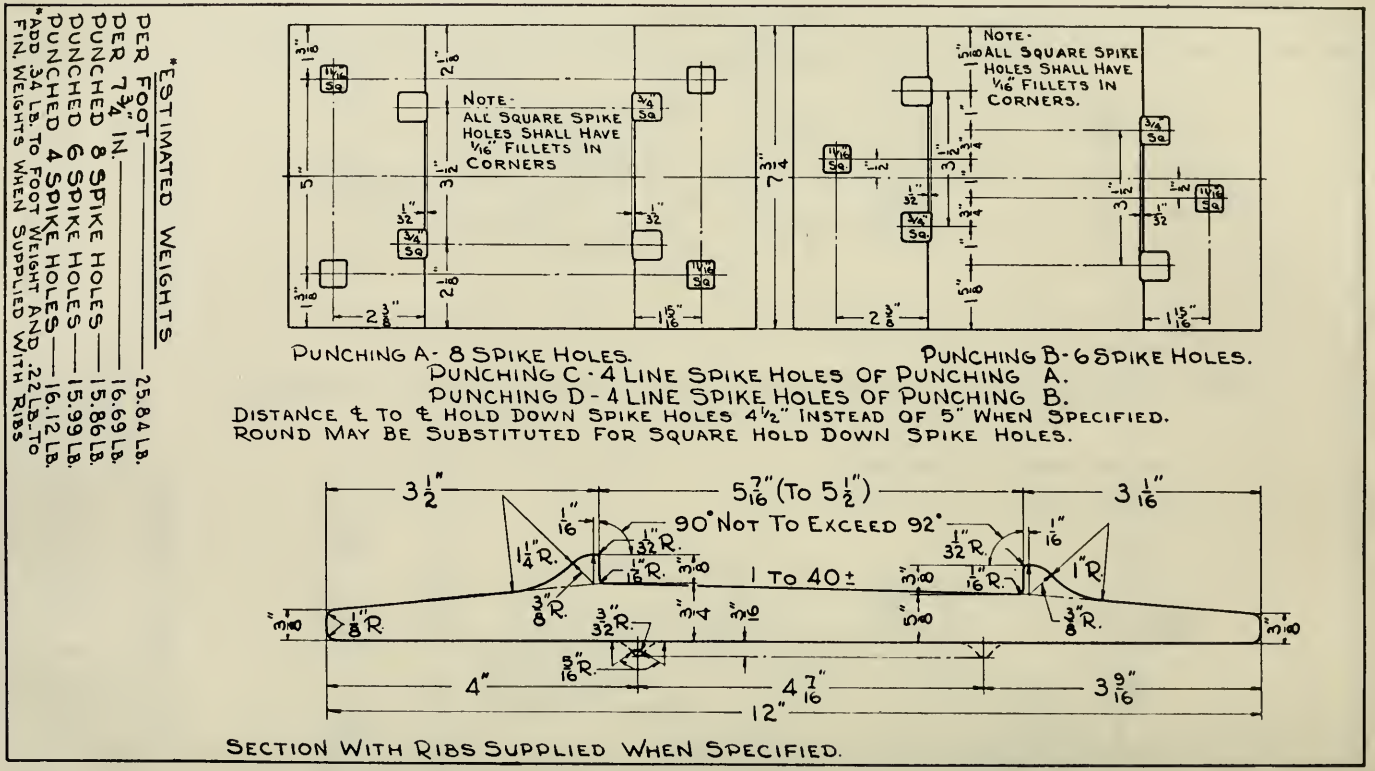

NOTE- ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS.
PUNCHING A - 7 SPIKE HOLES
PUNCHING B - 6 SPIKE HOLES
PUNCHING C - 4 LINE SPIKE HOLES OF PUNCHING A.
PUNCHING D - 4 LINE SPIKE HOLES OF PUNCHING B.
DISTANCE ℄ TO ℄ HOLD DOWN SPIKE HOLES 4½" INSTEAD OF 5" WHEN SPECIFIED.
"X" EQUALS 1/16 LESS THAN NOMINAL WIDTH OF BASE OF RAILS WITH WHICH TIE PLATE IS USED.
1 TO 40±
SECTION WITH RIBS SUPPLIED WHEN SPECIFIED.

*ESTIMATED WEIGHTS

PER FOOT	21.58 LB.
PER 7½ IN.	13.49 LB.
PUNCHED 7 SPIKE HOLES	12.87 LB.
PUNCHED 6 SPIKE HOLES	12.93 LB.
PUNCHED 4 SPIKE HOLES	13.05 LB.

*ADD .34 LB. TO FOOT WEIGHT AND .21 LB. TO FIN. WEIGHTS WHEN SUPPLIED WITH RIBS.

Fig. 2.—AISI 11-in. Tie Plate for Use with Rails 5½-in. to 5⅝-in. Base Width.


NOTE-
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS
NOTE-
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS.
PUNCHING A- 8 SPIKE HOLES.
PUNCHING B- 6 SPIKE HOLES.
PUNCHING C - 4 LINE SPIKE HOLES OF PUNCHING A.
PUNCHING D - 4 LINE SPIKE HOLES OF PUNCHING B.
DISTANCE ℄ TO ℄ HOLD DOWN SPIKE HOLES 4 1/2" INSTEAD OF 5" WHEN SPECIFIED.
ROUND MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.
3 1/2"
5 7/16" (To 5 1/2")
3 1/16"
90° NOT TO EXCEED 92°
1 TO 40±
4"
4 7/16"
3 9/16"
12"
SECTION WITH RIBS SUPPLIED WHEN SPECIFIED.

*ESTIMATED WEIGHTS

PER FOOT	
PER 7¾ IN.	25.84 LB.
PUNCHED 8 SPIKE HOLES	16.69 LB.
PUNCHED 6 SPIKE HOLES	15.86 LB.
PUNCHED 4 SPIKE HOLES	15.99 LB.

*ADD 34 LB. TO FOOT WEIGHT AND .22 LB. TO FIN. WEIGHTS WHEN SUPPLIED WITH RIBS

Fig. 3.—AISI 12-in. Tie Plate for Use with Rails with 5⅜-in. Base Width.

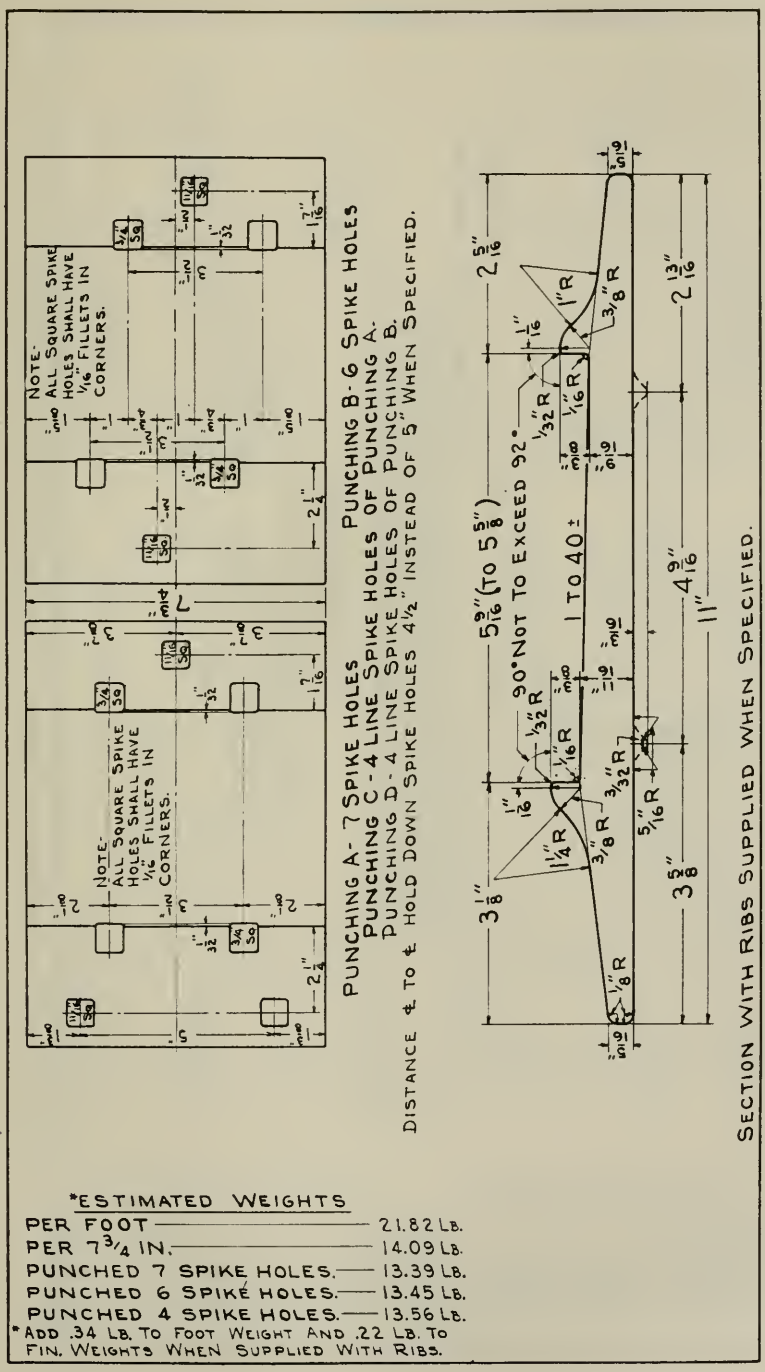

NOTE- ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS.
PUNCHING A- 7 SPIKE HOLES
PUNCHING B- 6 SPIKE HOLES
PUNCHING C- 4 LINE SPIKE HOLES OF PUNCHING A.
PUNCHING D- 4 LINE SPIKE HOLES OF PUNCHING B.
DISTANCE ℄ TO ℄ HOLD DOWN SPIKE HOLES 4½" INSTEAD OF 5" WHEN SPECIFIED.
SECTION WITH RIBS SUPPLIED WHEN SPECIFIED.
90° NOT TO EXCEED 92°
1 TO 40±
*ESTIMATED WEIGHTS
PER FOOT — 21.82 LB.
PER 7 3/4 IN. — 14.09 LB.
PUNCHED 7 SPIKE HOLES. — 13.39 LB.
PUNCHED 6 SPIKE HOLES. — 13.45 LB.
PUNCHED 4 SPIKE HOLES. — 13.56 LB.
*ADD .34 LB. TO FOOT WEIGHT AND .22 LB. TO FIN. WEIGHTS WHEN SUPPLIED WITH RIBS.

Fig. 4.—AISI 11-in. Tie Plate for Use with Rails with 5½-in. Base Width.

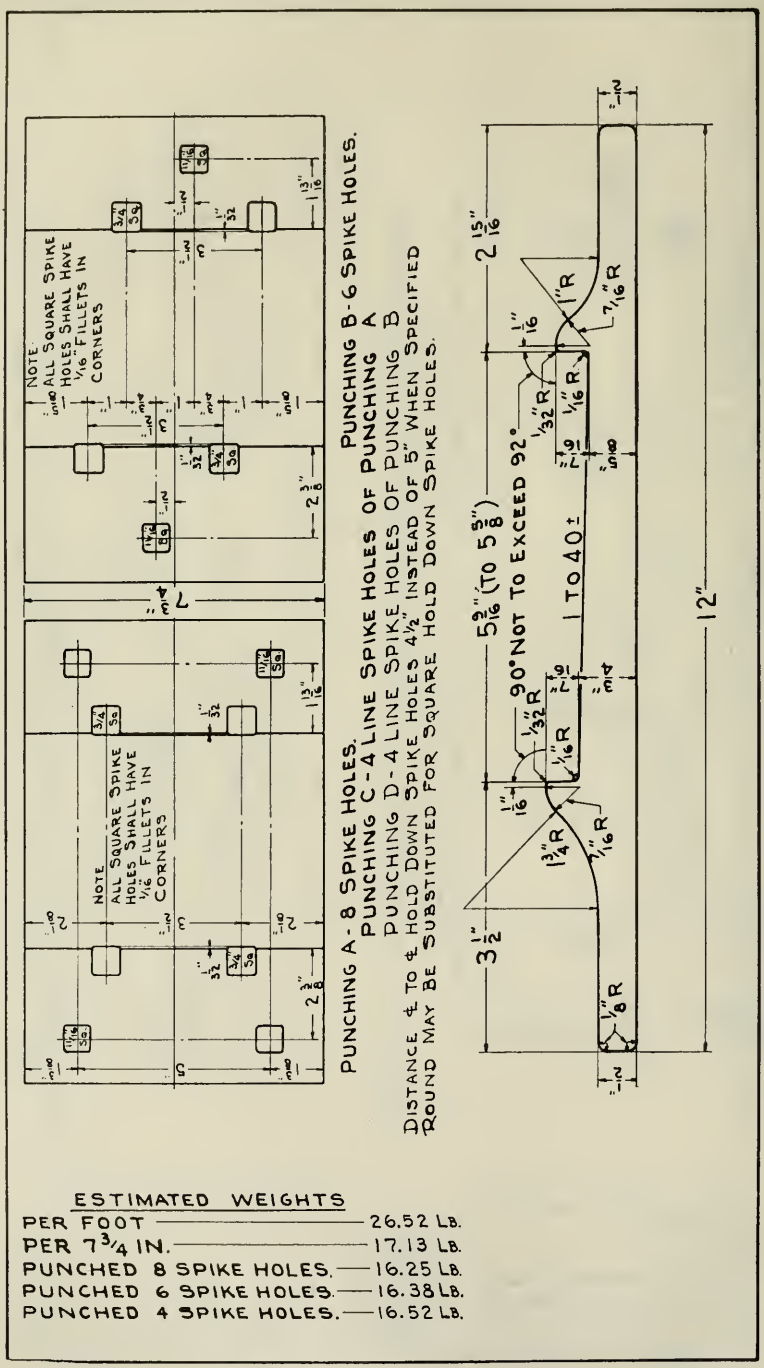
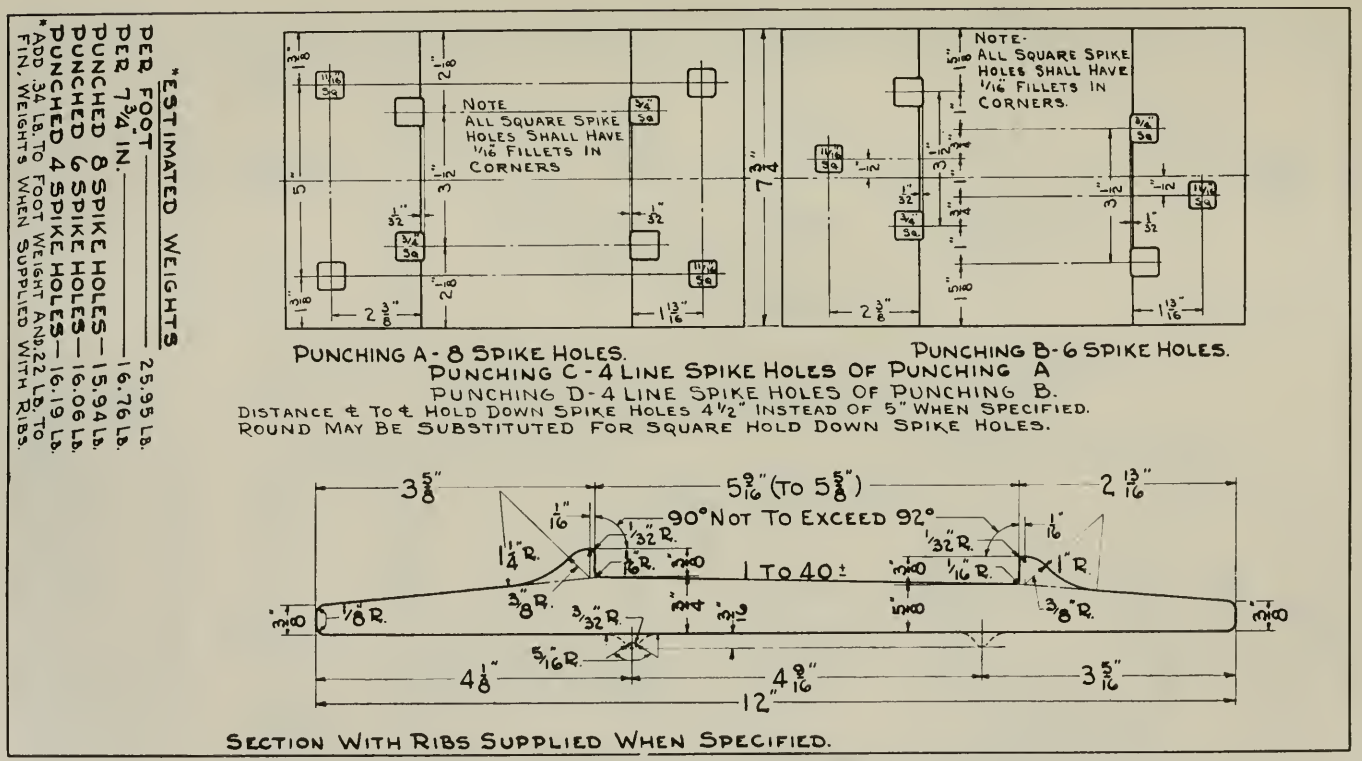

PUNCHING A - 8 SPIKE HOLES.
PUNCHING C - 4 LINE SPIKE HOLES OF PUNCHING A
PUNCHING D - 4 LINE SPIKE HOLES OF PUNCHING B
DISTANCE ℄ TO ℄ HOLD DOWN SPIKE HOLES 4½" INSTEAD OF 5" WHEN SPECIFIED
ROUND MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.
PUNCHING B - 6 SPIKE HOLES.
NOTE
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS
5 13/16" (TO 5 5/8")
90° NOT TO EXCEED 92°
1 TO 40±
2 15/16"
3 1/2"
12"
ESTIMATED WEIGHTS
PER FOOT — 26.52 LB.
PER 7 3/4 IN. — 17.13 LB.
PUNCHED 8 SPIKE HOLES. — 16.25 LB.
PUNCHED 6 SPIKE HOLES. — 16.38 LB.
PUNCHED 4 SPIKE HOLES. — 16.52 LB.

Fig. 5.—AISI 12-in. Tie Plate, with Flat Ends, for Use with Rails with 5½-in. Base Width.


NOTE
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16 FILLETS IN CORNERS
NOTE
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16 FILLETS IN CORNERS.
PUNCHING A - 8 SPIKE HOLES.
PUNCHING B - 6 SPIKE HOLES.
PUNCHING C - 4 LINE SPIKE HOLES OF PUNCHING A
PUNCHING D - 4 LINE SPIKE HOLES OF PUNCHING B.
DISTANCE ℄ TO ℄ HOLD DOWN SPIKE HOLES 4 1/2" INSTEAD OF 5" WHEN SPECIFIED.
ROUND MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.
90° NOT TO EXCEED 92°
1 TO 40 ±
SECTION WITH RIBS SUPPLIED WHEN SPECIFIED.

*ESTIMATED WEIGHTS

PER FOOT	25.95 LB.
PER 7¾ IN.	16.76 LB.
PUNCHED 8 SPIKE HOLES	15.94 LB.
PUNCHED 6 SPIKE HOLES	16.06 LB.
PUNCHED 4 SPIKE HOLES	16.19 LB.

*ADD .34 LB. TO FOOT WEIGHT AND 22 LB. TO F.N. WEIGHTS WHEN SUPPLIED WITH RIBS.

Fig. 6.—AISI 12-in. Tie Plate, with Inclined Ends, for Use with Rails with 5½-in. Base Width.

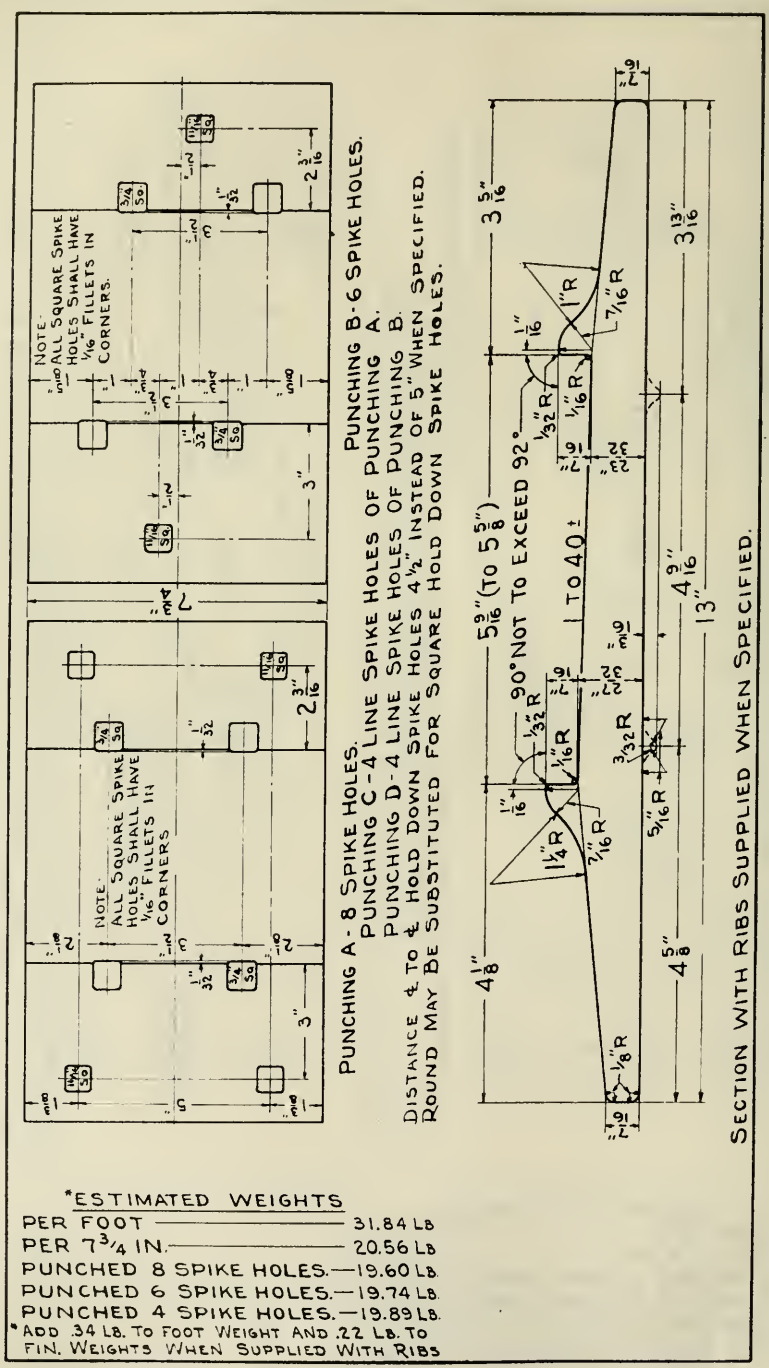

NOTE:
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS.
PUNCHING A-8 SPIKE HOLES.
PUNCHING C-4 LINE SPIKE HOLES OF PUNCHING A.
PUNCHING B-6 SPIKE HOLES.
PUNCHING D-4 LINE SPIKE HOLES OF PUNCHING B.
DISTANCE ℄ TO ℄ HOLD DOWN SPIKE HOLES 4½" INSTEAD OF 5" WHEN SPECIFIED.
ROUND MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.
SECTION WITH RIBS SUPPLIED WHEN SPECIFIED.
*ESTIMATED WEIGHTS
PER FOOT — 31.84 LB
PER 7 3/4 IN. — 20.56 LB
PUNCHED 8 SPIKE HOLES.—19.60 LB.
PUNCHED 6 SPIKE HOLES.—19.74 LB.
PUNCHED 4 SPIKE HOLES.—19.89 LB.
*ADD .34 LB. TO FOOT WEIGHT AND .22 LB. TO FIN. WEIGHTS WHEN SUPPLIED WITH RIBS

Fig. 7.—AISI 13-in. Tie Plate for Use with Rails with 5½-in. Base Width.

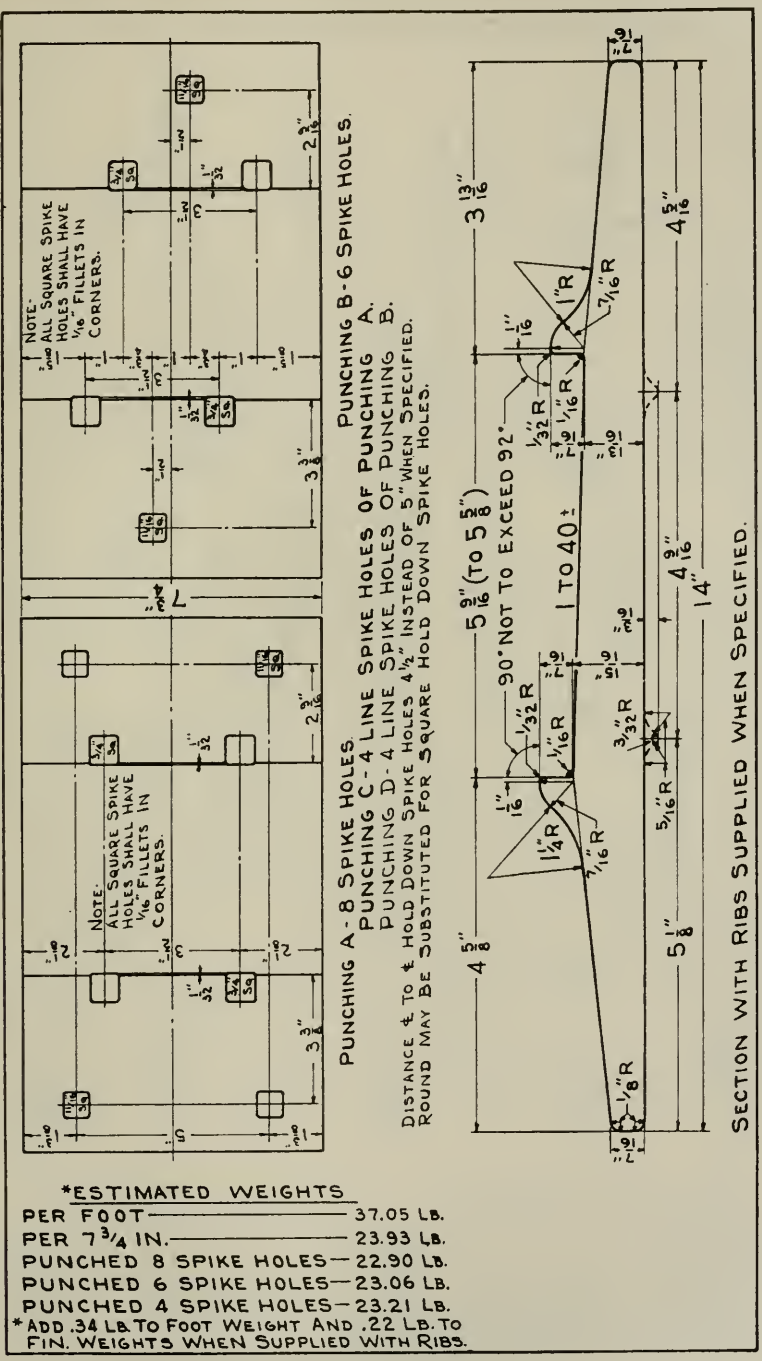

PUNCHING A-8 SPIKE HOLES
PUNCHING C-4 LINE SPIKE HOLES OF PUNCHING A.
PUNCHING D-4 LINE SPIKE HOLES OF PUNCHING B.
DISTANCE ℄ TO ℄ HOLD DOWN SPIKE HOLES 4½" INSTEAD OF 5" WHEN SPECIFIED. ROUND MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.
PUNCHING B-6 SPIKE HOLES.
NOTE: ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS.
NOTE: ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS.
5 9/16" (TO 5 5/8")
90° NOT TO EXCEED 92°
1 TO 40±
3 13/16"
4 5/8"
4 5/16"
4 9/16"
14"
5 1/8"
SECTION WITH RIBS SUPPLIED WHEN SPECIFIED.
*ESTIMATED WEIGHTS
PER FOOT — 37.05 LB.
PER 7 3/4 IN. — 23.93 LB.
PUNCHED 8 SPIKE HOLES — 22.90 LB.
PUNCHED 6 SPIKE HOLES — 23.06 LB.
PUNCHED 4 SPIKE HOLES — 23.21 LB.
*ADD .34 LB. TO FOOT WEIGHT AND .22 LB. TO FIN. WEIGHTS WHEN SUPPLIED WITH RIBS.

Fig. 8.—AISI 14-in. Tie Plate for Use with Rails with 5½-in. Base Width.

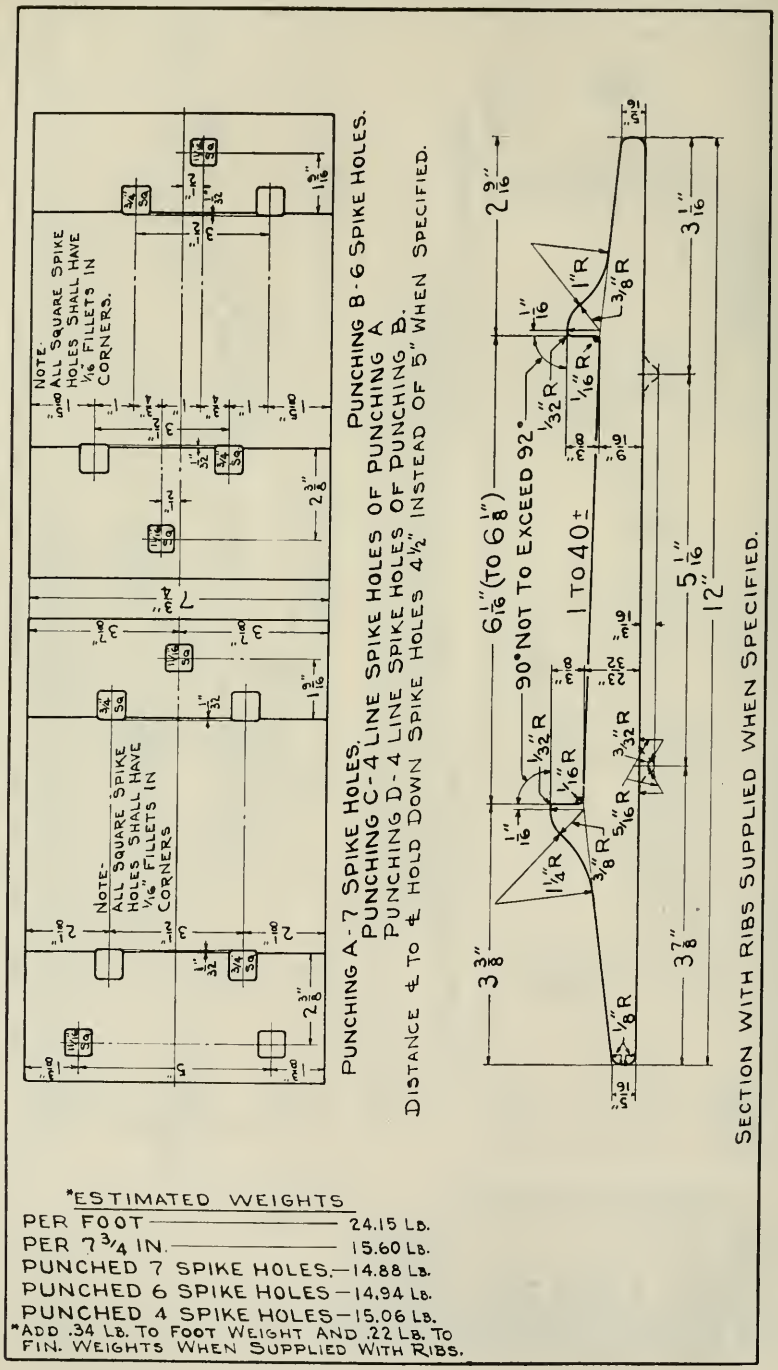
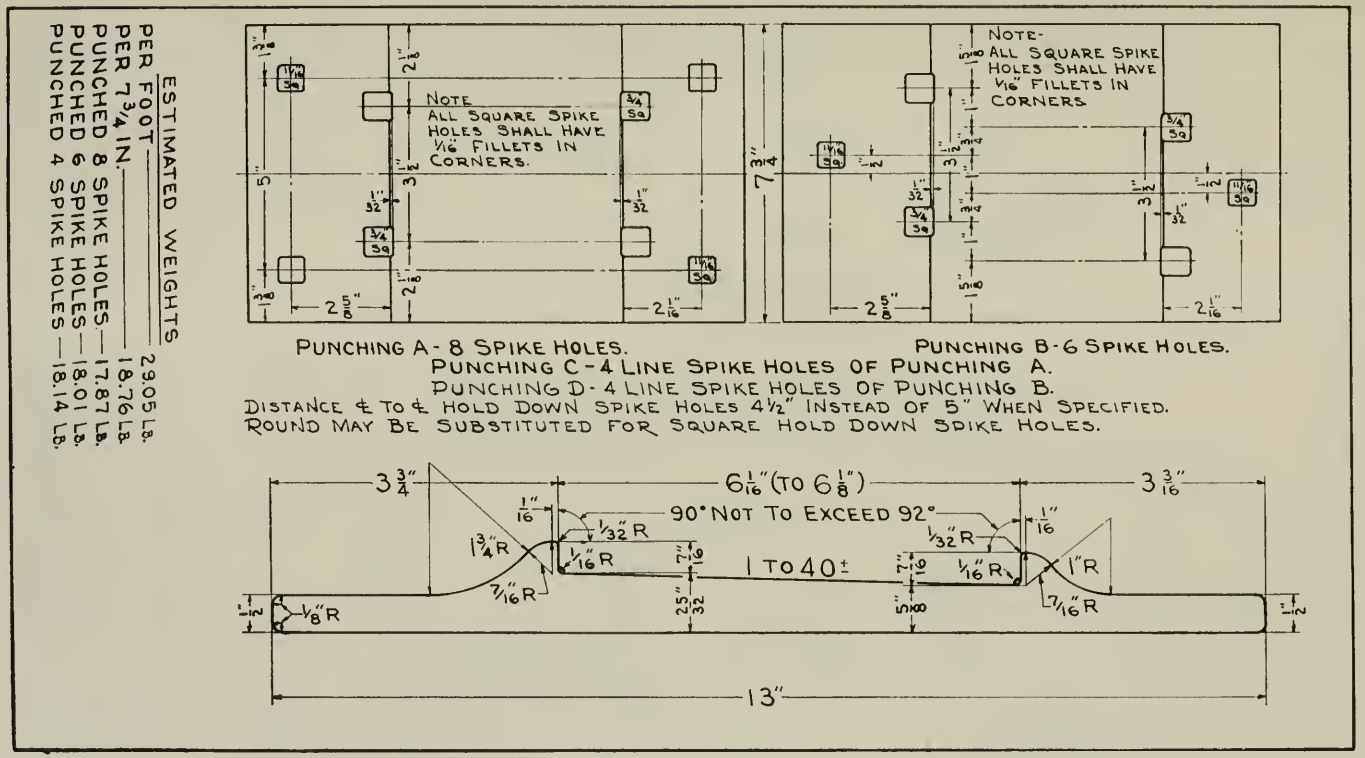

NOTE-
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS.
PUNCHING A-7 SPIKE HOLES.
PUNCHING B-6 SPIKE HOLES.
PUNCHING C-4 LINE SPIKE HOLES OF PUNCHING A
PUNCHING D-4 LINE SPIKE HOLES OF PUNCHING B.
DISTANCE ℄ TO ℄ HOLD DOWN SPIKE HOLES 4½" INSTEAD OF 5" WHEN SPECIFIED.
SECTION WITH RIBS SUPPLIED WHEN SPECIFIED.
*ESTIMATED WEIGHTS
PER FOOT — 24.15 LB.
PER 7 3/4 IN. — 15.60 LB.
PUNCHED 7 SPIKE HOLES.—14.88 LB.
PUNCHED 6 SPIKE HOLES—14.94 LB.
PUNCHED 4 SPIKE HOLES—15.06 LB.
*ADD .34 LB. TO FOOT WEIGHT AND .22 LB. TO FIN. WEIGHTS WHEN SUPPLIED WITH RIBS.

Fig. 9.—AISI 12-in. Tie Plate for Use with Rails with 6-in. Base Width.


NOTE
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS.
NOTE-
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS
PUNCHING A - 8 SPIKE HOLES.
PUNCHING B - 6 SPIKE HOLES.
PUNCHING C - 4 LINE SPIKE HOLES OF PUNCHING A.
PUNCHING D - 4 LINE SPIKE HOLES OF PUNCHING B.
DISTANCE ℄ TO ℄ HOLD DOWN SPIKE HOLES 4½" INSTEAD OF 5" WHEN SPECIFIED.
ROUND MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.
90° NOT TO EXCEED 92°
1 TO 40±
13"

ESTIMATED WEIGHTS

PER FOOT—

PER 7¾ IN.—

PUNCHED 8 SPIKE HOLES—17.87 LB.

PUNCHED 6 SPIKE HOLES—18.01 LB.

PUNCHED 4 SPIKE HOLES—18.14 LB.

29.05 LB.

18.76 LB.

Fig. 10.—AISI 13-in. Tie Plate, with Flat Ends, for Use with Rails with 6-in. Base Width.

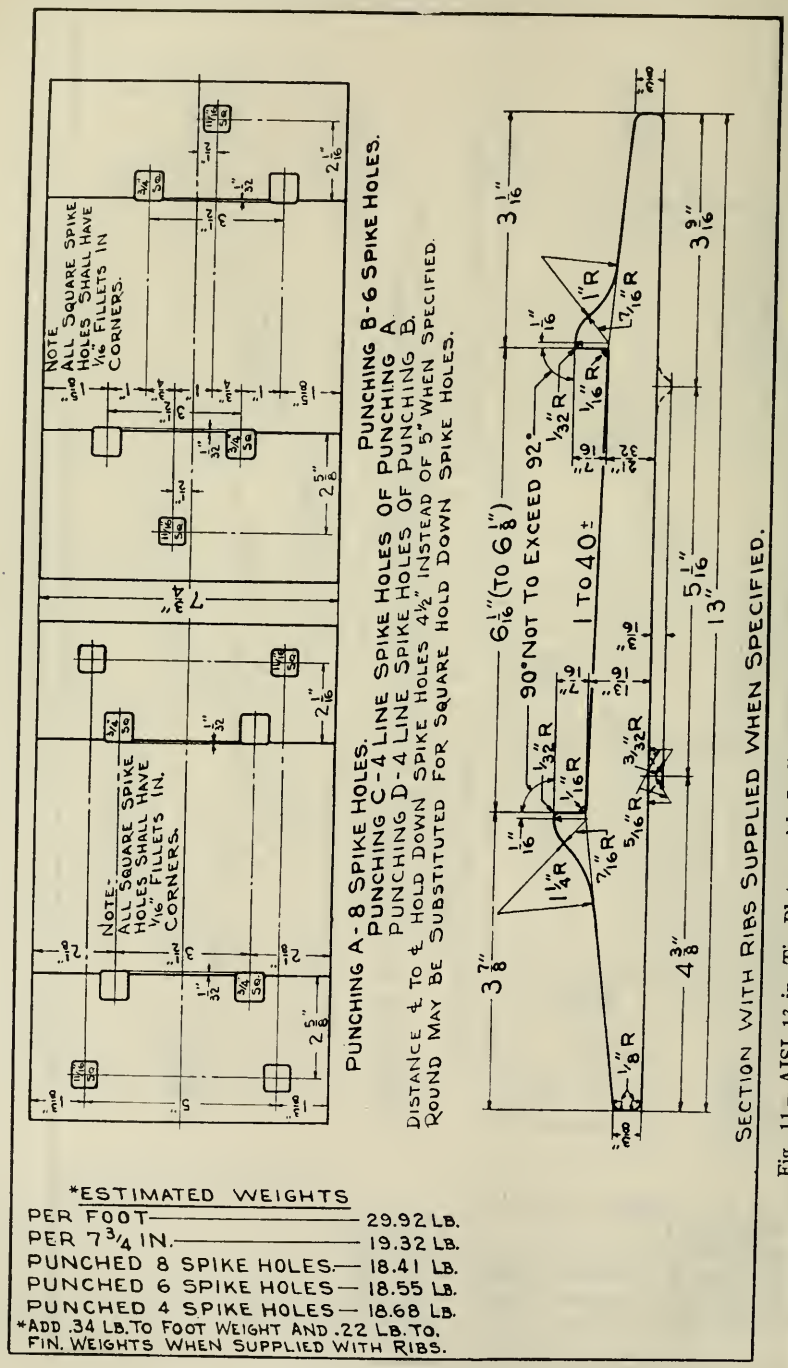
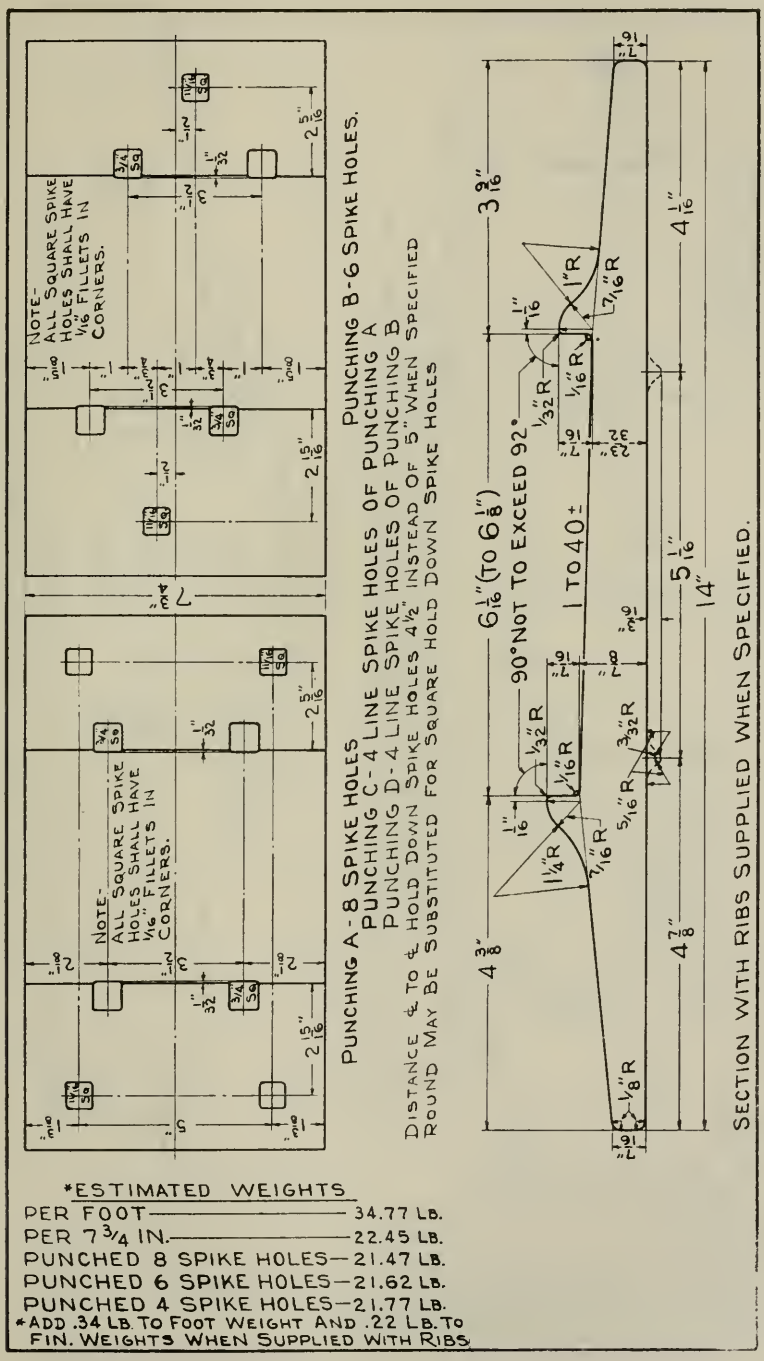

NOTE
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16 FILLETS IN CORNERS.
PUNCHING A-8 SPIKE HOLES.
PUNCHING B-6 SPIKE HOLES.
PUNCHING C-4 LINE SPIKE HOLES OF PUNCHING A.
PUNCHING D-4 LINE SPIKE HOLES OF PUNCHING B.
DISTANCE ¼ TO ¾ HOLD DOWN SPIKE HOLES 4½" INSTEAD OF 5" WHEN SPECIFIED.
ROUND MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.
SECTION WITH RIBS SUPPLIED WHEN SPECIFIED.
*ESTIMATED WEIGHTS
PER FOOT — 29.92 LB.
PER 7 3/4 IN. — 19.32 LB.
PUNCHED 8 SPIKE HOLES — 18.41 LB.
PUNCHED 6 SPIKE HOLES — 18.55 LB.
PUNCHED 4 SPIKE HOLES — 18.68 LB.
*ADD .34 LB. TO FOOT WEIGHT AND .22 LB. TO FIN. WEIGHTS WHEN SUPPLIED WITH RIBS.

Fig. 11.—AISI 13-in. Tie Plates, with Inclined Ends, for Use with Rails with 6-in. Base Width.


NOTE- ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS.
PUNCHING A-8 SPIKE HOLES
PUNCHING C-4 LINE SPIKE HOLES OF PUNCHING A
PUNCHING D-4 LINE SPIKE HOLES OF PUNCHING B
DISTANCE ℄ TO ℄ HOLD DOWN SPIKE HOLES 4½" INSTEAD OF 5" WHEN SPECIFIED
ROUND MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES
PUNCHING B-6 SPIKE HOLES.
6 1/16" (TO 6 1/8")
90° NOT TO EXCEED 92°
1 TO 40±
3 9/16"
4 3/8"
4 7/8"
5 1/16"
4 1/16"
14"
SECTION WITH RIBS SUPPLIED WHEN SPECIFIED.

*ESTIMATED WEIGHTS

PER FOOT	34.77 LB.
PER 7 3/4 IN.	22.45 LB.
PUNCHED 8 SPIKE HOLES	21.47 LB.
PUNCHED 6 SPIKE HOLES	21.62 LB.
PUNCHED 4 SPIKE HOLES	21.77 LB.

*ADD .34 LB. TO FOOT WEIGHT AND .22 LB. TO FIN. WEIGHTS WHEN SUPPLIED WITH RIBS

Fig. 12.—AISI 14-in. Tie Plate for Use with Rails with 6-in. Base Width.

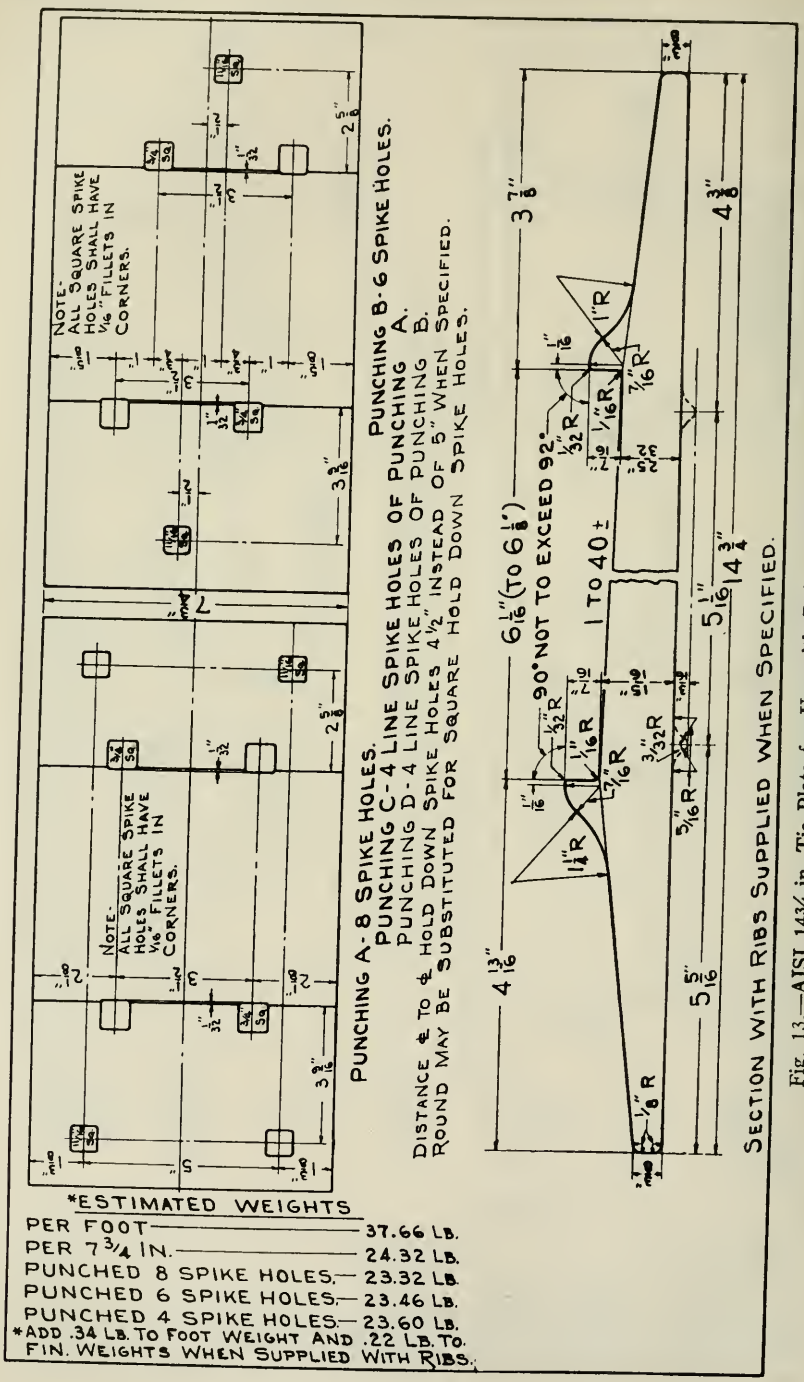
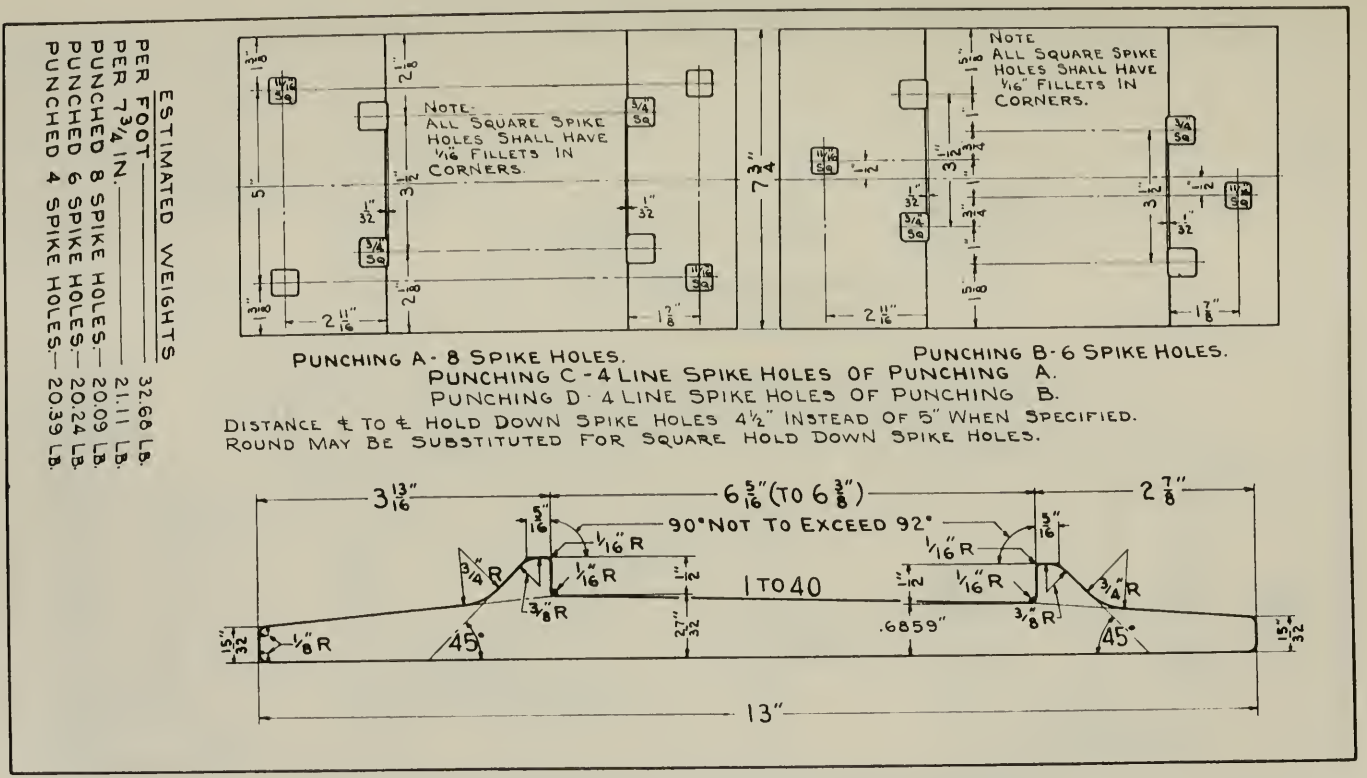

NOTE:
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS.
PUNCHING A-8 SPIKE HOLES.
PUNCHING C-4 LINE SPIKE HOLES OF PUNCHING A.
PUNCHING D-4 LINE SPIKE HOLES OF PUNCHING B.
DISTANCE ℄ TO ℄ HOLD DOWN SPIKE HOLES 4 1/2" INSTEAD OF 5" WHEN SPECIFIED.
ROUND MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.
PUNCHING B-6 SPIKE HOLES.
SECTION WITH RIBS SUPPLIED WHEN SPECIFIED.
*ESTIMATED WEIGHTS
PER FOOT — 37.66 LB.
PER 7 3/4 IN. — 24.32 LB.
PUNCHED 8 SPIKE HOLES — 23.32 LB.
PUNCHED 6 SPIKE HOLES — 23.46 LB.
PUNCHED 4 SPIKE HOLES — 23.60 LB.
*ADD .34 LB. TO FOOT WEIGHT AND .22 LB. TO FIN. WEIGHTS WHEN SUPPLIED WITH RIBS.

Fig. 13.—AISI 14¾-in. Tie Plate for Use with Rails with 6-in. Base Width.


NOTE
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS.
NOTE
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS.
7 3/4"
PUNCHING A - 8 SPIKE HOLES.
PUNCHING B - 6 SPIKE HOLES.
PUNCHING C - 4 LINE SPIKE HOLES OF PUNCHING A.
PUNCHING D - 4 LINE SPIKE HOLES OF PUNCHING B.
DISTANCE ℄ TO ℄ HOLD DOWN SPIKE HOLES 4½" INSTEAD OF 5" WHEN SPECIFIED.
ROUND MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.
3 13/16"
6 5/16" (TO 6 3/8")
2 7/8"
90° NOT TO EXCEED 92°
1/16" R
3/4" R
3/8" R
1 TO 40
.6859"
45°
1/8" R
13"

ESTIMATED WEIGHTS

PER FOOT	32.66 LB.
PER 7¾ IN.	21.11 LB.
PUNCHED 8 SPIKE HOLES	2009 LB.
PUNCHED 6 SPIKE HOLES	20.24 LB.
PUNCHED 4 SPIKE HOLES	20.39 LB.

Fig. 14.—AISI 13-in. Tie Plate for Use with Rails with 6¼-in. Base Width.

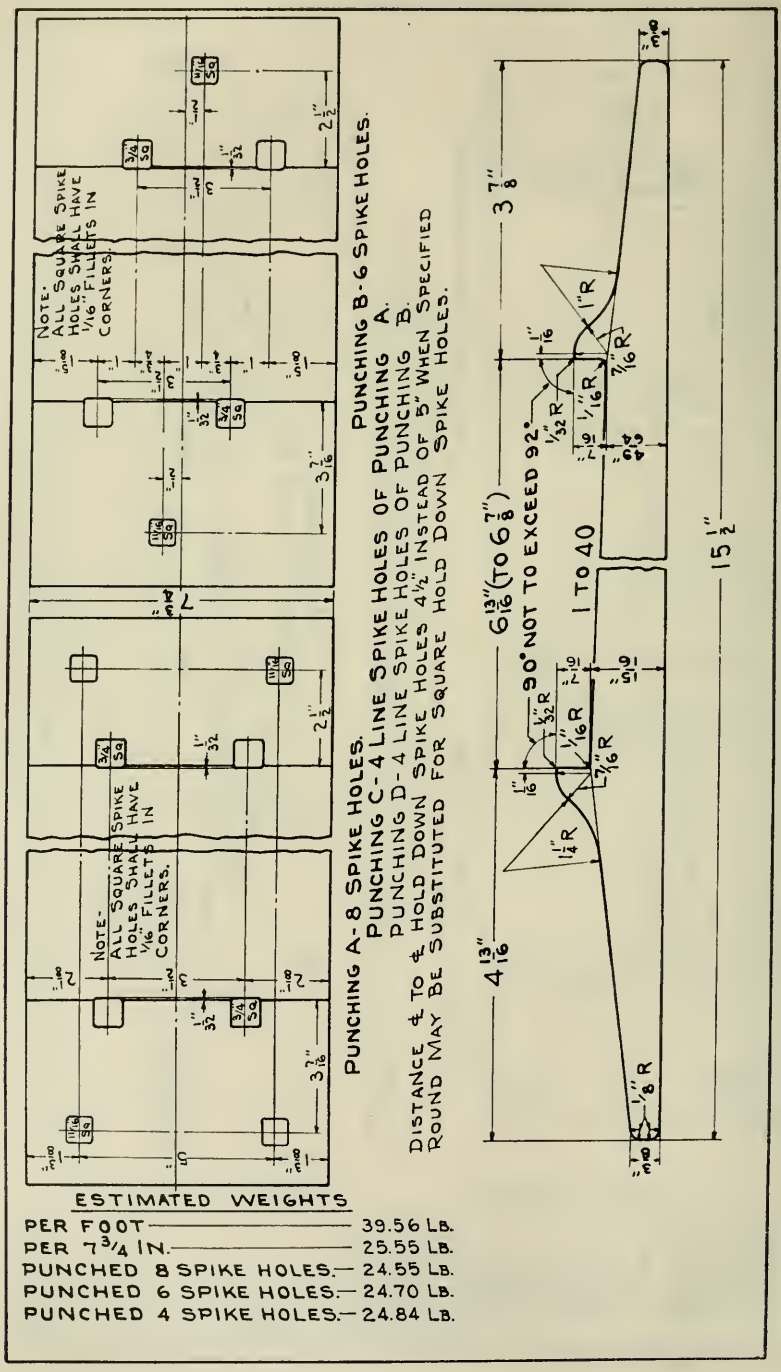

PUNCHING A-8 SPIKE HOLES.
PUNCHING C-4 LINE SPIKE HOLES OF PUNCHING A.
PUNCHING D-4 LINE SPIKE HOLES OF PUNCHING B.
DISTANCE ℄ TO ℄ HOLD DOWN SPIKE HOLES 4½" INSTEAD OF 5" WHEN SPECIFIED ROUND MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.
PUNCHING B-6 SPIKE HOLES.
NOTE- ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS.
ESTIMATED WEIGHTS
PER FOOT — 39.56 LB.
PER 7 3/4 IN. — 25.55 LB.
PUNCHED 8 SPIKE HOLES.— 24.55 LB.
PUNCHED 6 SPIKE HOLES.— 24.70 LB.
PUNCHED 4 SPIKE HOLES.— 24.84 LB.
6 13/16" (TO 6 7/8")
90° NOT TO EXCEED 92°
1 TO 40
3 7/8"
4 13/16"
15 1/2"

Fig. 15.—AISI 15½-in. Tie Plate for Use with Rails with 6¾-in. Base Width.

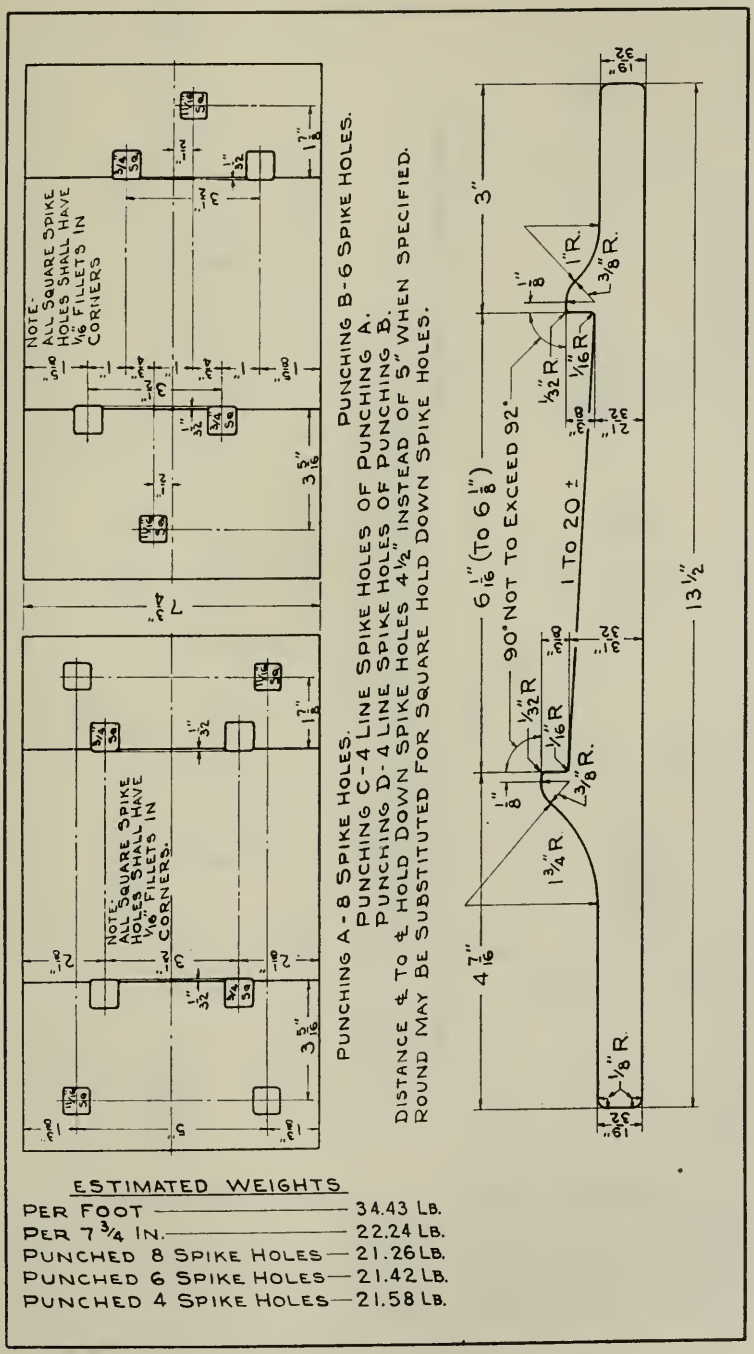

NOTE:
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16 FILLETS IN CORNERS
PUNCHING A-8 SPIKE HOLES.
PUNCHING C-4 LINE SPIKE HOLES OF PUNCHING A.
PUNCHING D-4 LINE SPIKE HOLES OF PUNCHING B.
DISTANCE ℄ TO ℄ HOLD DOWN SPIKE HOLES 4½" INSTEAD OF 5" WHEN SPECIFIED.
ROUND MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.
PUNCHING B-6 SPIKE HOLES.
6 1/16" (TO 6 1/8")
90° NOT TO EXCEED 92°
1 TO 20 ±
13½"
ESTIMATED WEIGHTS
PER FOOT — 34.43 LB.
PER 7 3/4 IN. — 22.24 LB.
PUNCHED 8 SPIKE HOLES — 21.26 LB.
PUNCHED 6 SPIKE HOLES — 21.42 LB.
PUNCHED 4 SPIKE HOLES — 21.58 LB.

Fig. 16.—AISI 13½-in. Tie Plate for Use with Rails with 6-in. Base Width.

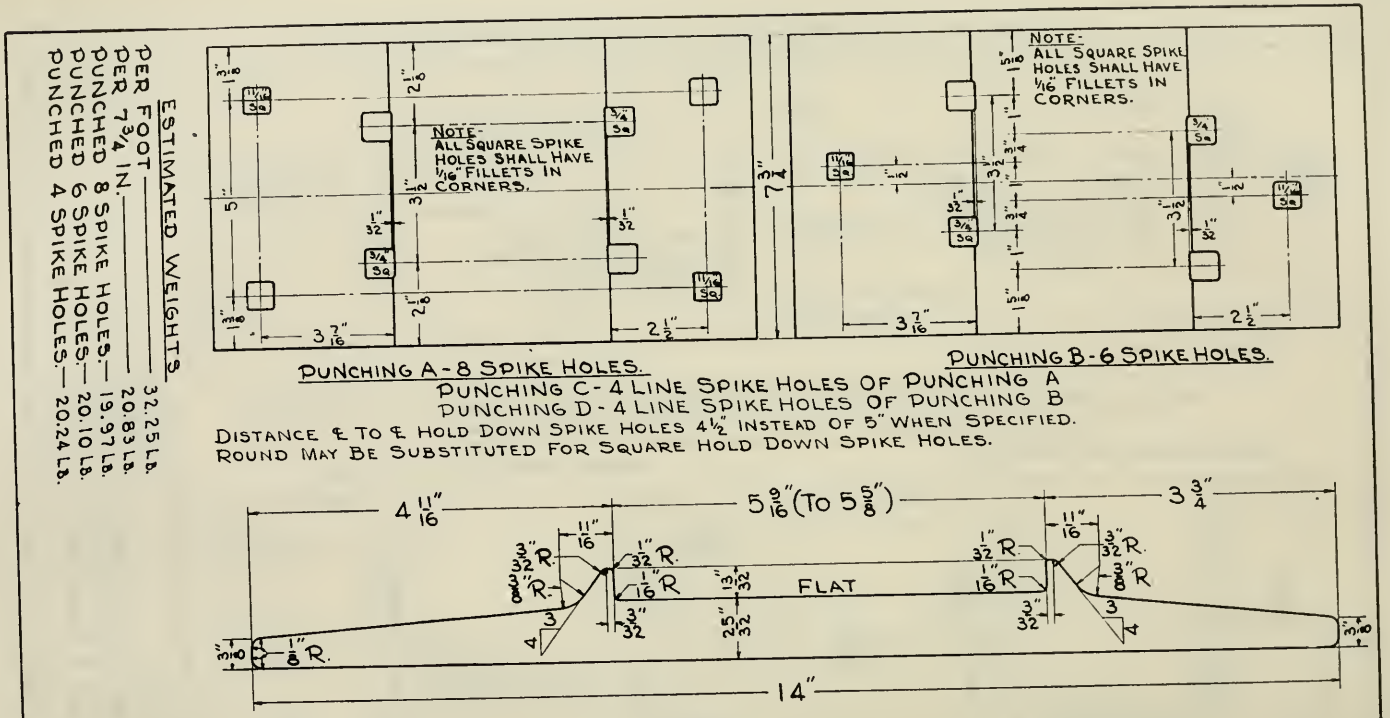
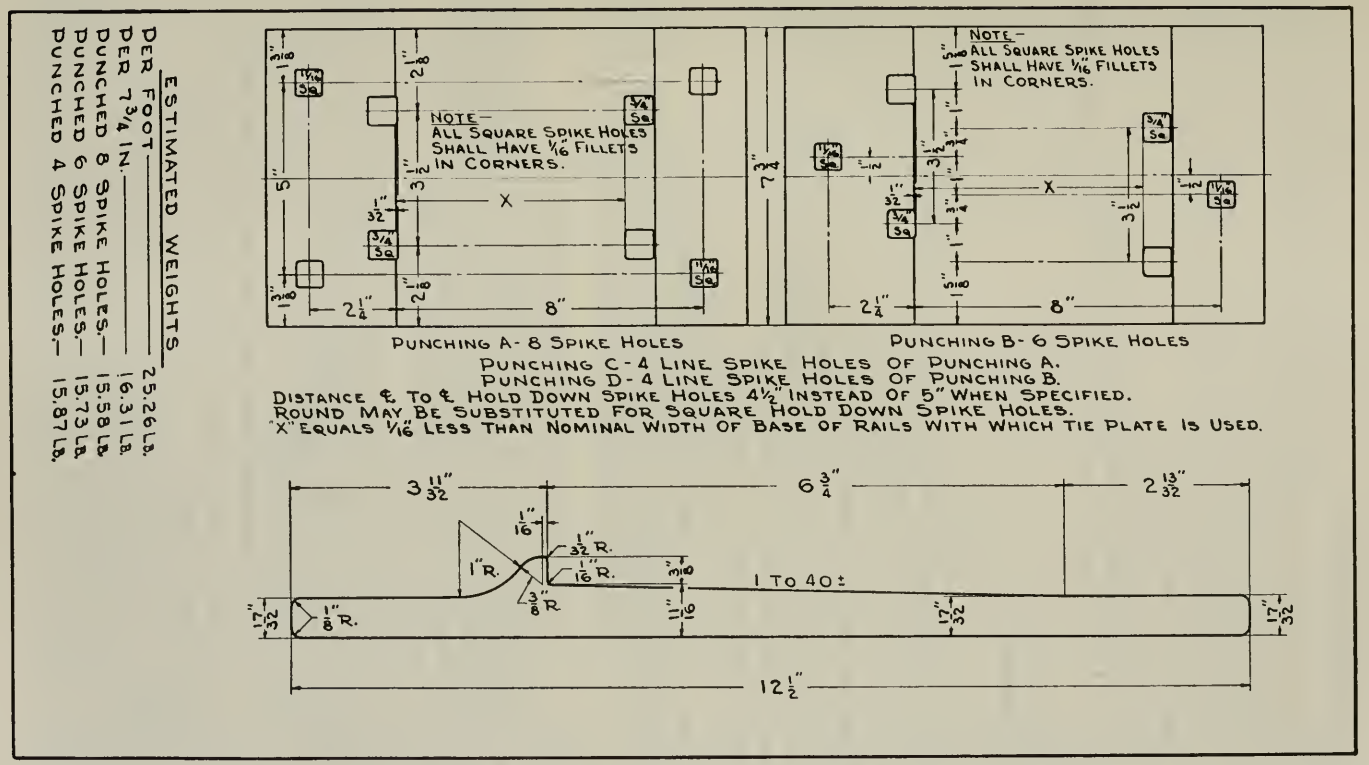

NOTE-
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS.
NOTE-
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS.
7 3/4"
PUNCHING A-8 SPIKE HOLES.
PUNCHING B-6 SPIKE HOLES.
PUNCHING C-4 LINE SPIKE HOLES OF PUNCHING A
PUNCHING D-4 LINE SPIKE HOLES OF PUNCHING B
DISTANCE ℄ TO ℄ HOLD DOWN SPIKE HOLES 4 1/2" INSTEAD OF 5" WHEN SPECIFIED.
ROUND MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.
4 11/16"
5 9/16" (TO 5 5/8")
3 3/4"
FLAT
14"
ESTIMATED WEIGHTS
PER FOOT ——— 32.25 LB.
PER 7 3/4 IN. ——— 20.83 LB.
PUNCHED 8 SPIKE HOLES— 19.97 LB.
PUNCHED 6 SPIKE HOLES— 20.10 LB.
PUNCHED 4 SPIKE HOLES— 20.24 LB.

Fig. 17.—AISI 14-in. Tie Plate for Use with Rails with 5½-in. Base Width.


NOTE—
ALL SQUARE SPIKE HOLES SHALL HAVE 1/16" FILLETS IN CORNERS.
PUNCHING A- 8 SPIKE HOLES
PUNCHING B- 6 SPIKE HOLES
PUNCHING C - 4 LINE SPIKE HOLES OF PUNCHING A.
PUNCHING D - 4 LINE SPIKE HOLES OF PUNCHING B.
DISTANCE ℄ TO ℄ HOLD DOWN SPIKE HOLES 4½" INSTEAD OF 5" WHEN SPECIFIED.
ROUND MAY BE SUBSTITUTED FOR SQUARE HOLD DOWN SPIKE HOLES.
"X" EQUALS 1/16 LESS THAN NOMINAL WIDTH OF BASE OF RAILS WITH WHICH TIE PLATE IS USED.
1 TO 40±
12½"

ESTIMATED WEIGHTS

PER FOOT	25.26 LB.
PER 7¾ IN.	16.31 LB.
PUNCHED 8 SPIKE HOLES—	15.58 LB.
PUNCHED 6 SPIKE HOLES—	15.73 LB.
PUNCHED 4 SPIKE HOLES—	15.87 LB.

Fig. 18.—AISI 12½-in. Tie Plate for Use with Rails with 6½-in. to 6-in. Base Width.

(text continued from page 337)

Page 5–1

Substitute the following revisions in the title and paragraphs of similar number in the Specifications for Soft and Medium Steel Tie Plates.

SPECIFICATIONS FOR LOW CARBON STEEL TIE PLATES

Change date of 1946 to 1948.

Delete paragraph under date 1946.

Delete current paragraph 101 and substitute the following:

101. The steel may be made by the bessemer, open-hearth or electric-furnace process, or by both.

Change paragraph 201 (b) to read as follows:

(b) Phosphorus

Bessemer—not over 0.11 percent.

Open-hearth or electric furnace—not over 0.05 percent.

Replace last four lines of paragraph 201 (c) by the following:

Bessemer—not under 0.08 percent.

Open-hearth—not under 0.15 percent.

Change first sentence of paragraph 202 to read:

202. Carbon and manganese determinations shall be made on each blow of bessemer steel, and determinations for phosphorus and sulfur shall be at intervals of not greater than each 10 blows, and the next previous determination may be reported.

Delete the last two lines of paragraph 301.

Delete "where bent for the soft grade, and to twice the thickness of the section where bent for the medium grade," in the indented paragraph of 303.

Delete current paragraph 304 (a) and substitute the following:

304. (a) One bend test shall be made from each melt of open-hearth steel, from each melt or lot of 10 tons of bessemer steel, or from each 25 tons where melts are not identified.

Delete current paragraph 401 (b) and substitute the following:

(b) For tie plates with rolled crown, a variation of 1/32 in. over or 1/32 in. under in thickness, 3/16 in. over 3/16 in. under in rolled width, ¼ in. over or ¼ in. under in sheared length, ¼ in. plus and minus for the dimension from the middle of the crown to the sheared edges, and ¼ in. plus and minus the nominal dimensions for the distance from the center of the spike holes to the sheared edges.

Add new paragraph (f) to 401.

(f) A variation of 1/32 in. under and 1/64 in. over in the height of the shoulders.

Paragraph 402, first line, delete the words "true to templet."

Paragraph 501, first line, delete the words "the section," and substitute therefor "the AREA section number of the tie plate."

Page 5–14.1 Substitute the following revisions in the paragraphs of similar number in:

Specifications for Hot-Worked, High-Carbon Steel Tie Plates

Change date of 1941 to 1948.

Paragraph 201, third line, change figures "0.40 to 0.80" to "0.35—0.82."

Paragraph 201, add fifth line as follows:

Copper, when specified, minimum percent 0.20

Paragraph 302, first line, delete the word "specified."

Delete current 401 (a), (b), (c), (d), (e) and (f), and substitute therefor the following:

(a) For tie plates with shoulders parallel to the direction of rolling, a variation of 1/32 in. over or 1/32 in. under in thickness, ⅛ in. over or ⅛ in. under in rolled width, and 3/16 in. over or 3/16 in. under in sheared length.

(b) For tie plates with rolled crown, a variation of 1/32 in. over or 1/32 in. under in thickness, 3/16 in. over or 3/16 in. under in rolled width, and ¼ in. over or ¼ in. under in sheared length, ¼ in. plus and minus for the dimensions from the middle of the crown to the sheared edges and ¼ in. plus and minus the nominal dimensions for the distance from the center of the spike holes to the sheared edges.

(c) A variation of 0.025 in. over or 0.025 in. under in flatness of rail seat.

(d) A variation of 1/16 in. over the minimum dimensions specified for distance between the shoulders of double-shoulder tie plates.

(e) A variation of 1/32 in. over or 1/32 in. under in the location of spike holes and in the length or width of their sides.

(f) A variation of 1/32 in. under and 1/64 in. over in the height of the shoulders.

Paragraph 402, first line, delete the words "true to templet."

Add new paragraph 403.

403. Tie plates shall be paid for on the basis of actual weight as applied to the entire order, except that payment shall not be made for any weight in excess of 3 percent over the weight calculated from the specified dimensions.

Paragraph 501, first line, delete the words "the section," and substitute therefor "the AREA section number."

Report on Assignment 7

Hold-Down Fastenings for Tie Plates; Design, Use and Economy With Respect to Minimizing Tie Wear

Collaborating with Committee 3

Blair Blowers (chairman, subcommittee), L. L. Adams, C. A. Anderson, F. J. Bishop, J. A. Blalock, H. J. Bogardus, A. E. Botts, E. J. Brown, E. W. Caruthers, R. W. Claypoole, E. D. Cowlin, H. F. Fifield, J. W. Fulmer, C. E. Haight, H. H. Harman, J. P. Hiltz, A. F. Huber, J. de N. Macomb, G. M. Magee, E. E. Martin, F. H. Masters, J. A. Reed, M. K. Ruppert, I. H. Schram, Troy West, M. J. Zeeman.

Last year your committee submitted a report on a service test of several arrangements of hold-down spikes on the Illinois Central System, and now submits the following further report of progress, as information, in the tests of hold-down fastenings.

Mechanical wear of ties can be reduced by the use of larger tie plates or by the application of effective types of hold-down fastenings. Investigations being conducted in connection with Assignment 6—Design of and stresses in tie plates, are expected to develop information on the economical size of tie plates with respect to traffic density. The test installations of hold-down fastenings will indicate the relative effectiveness and economy of the several types of tie plate anchorage and tie pads in relation to reduction of mechanical wear of ties and gage widening on curves caused by unequal tie plate penetration with the resulting outward cant of the rails. It is believed that the information to be obtained for these two assignments will provide the basis for the determination of the most economical size of tie plate and the most effective hold-down fastenings, in order to secure maximum utilization of the service life of ties.

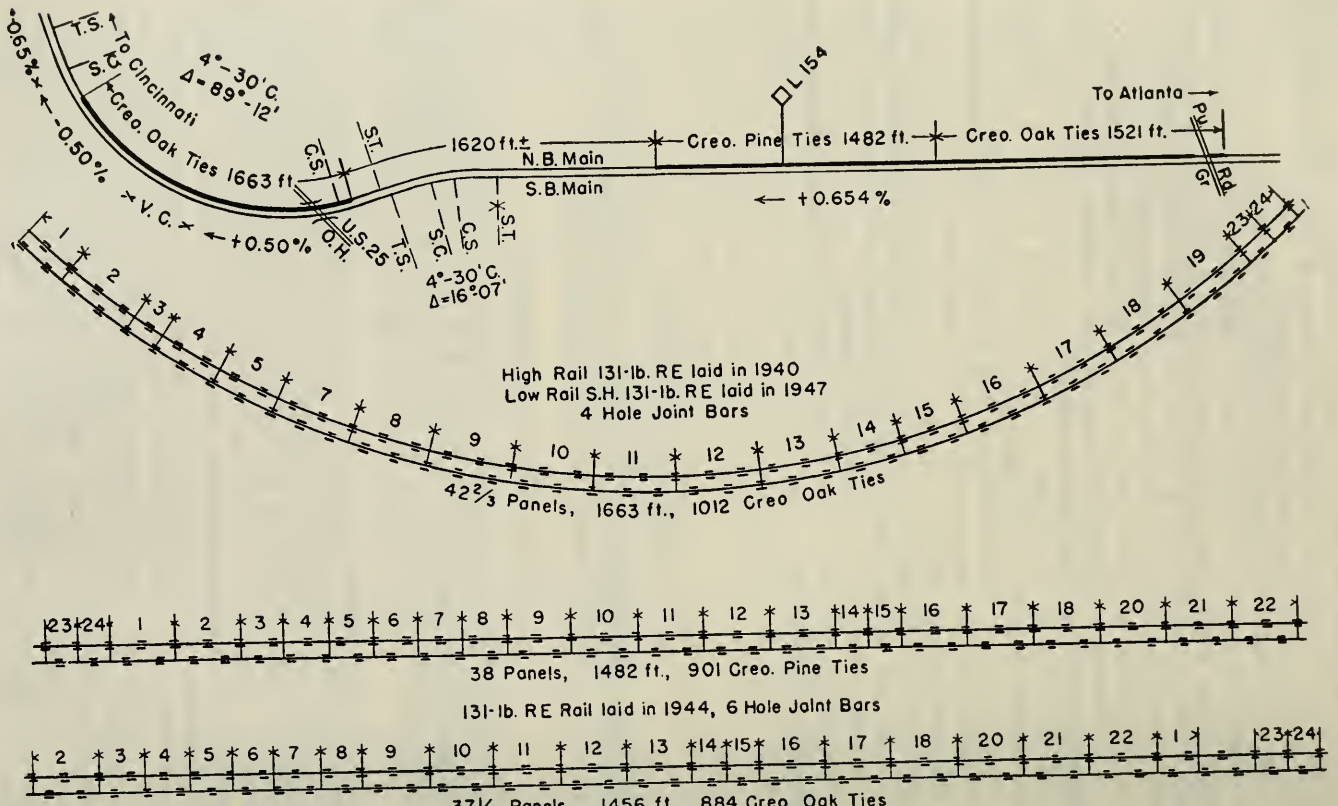


Fig. 1.—Plan of Test Track.

Table 1 - Description of Test Sections as Shown in Fig. 1

Section No.	No. of Test Ties: Creo. Oak Tang.	No. of Test Ties: Pine Tang.	Total	Number and Type of Hold-Down Fastenings per Tie Plate and Tie Pads (131-lb. RE Rail)
1				Adhesives - no anchor spikes - subdivided as follows.
1.1	11	12	29	Beckosol No. 40. Heated and applied to bottom of tie plate with a paddle
1.2	9	9	27	Waterproofing Asphalt, AREA Specifications. Applied in the same manner as above
1.3	0	6	10	CASCO Flexible Cement NT-442. Applied to tie plate and tie in the field
1.4	3	6	12	NT-442 Cement applied to tie plate as a primer and CASCO PHEN RS-216 applied to tie plate and tie in the field
1.5	9	9	27	Same as subsection 1.4 except the tie plates were cemented to the ties before creosoting
1.6	2	0	2	Premolded sheet of asphalt, 1/8 in. thick, made of regular Bird tie pad coating, designated No. 52
1.7	2	0	2	Premolded sheet of asphalt, 1/8 in. thick, made of regular Bird tie pad coating modified to further reduce flow, designated No. 53
1.8	2	0	2	Same as No. 53 except the asphalt was formed around brass screening, designated No. 54
1.9	2	0	2	Same as No. 53 except the asphalt was formed around 1/4 in. mesh galvanized screening, designated No. 55
2	59	47	48	154 No anchor spikes
3	24	31	32	87 1-ply Bird tie pads, no anchor spikes
4	47	32	32	111 5-ply Bird tie pads, no anchor spikes
5	49	31	32	112 7-ply Bird tie pads, no anchor spikes
6	0	32	32	64 No anchor spikes, 2 Racor Drive Tight (Sandberg) line spikes
7	58	32	32	122 2 each of Racor Drive Tight (Sandberg) line and anchor spikes
8	60	31	32	123 2 cut spikes for line and 2 Racor Drive Tight (Sandberg) anchor spikes
9	59	48	48	155 2 each of cut spikes for line and anchors
10	59	47	49	155 2 cut spikes for line and 2 round head cut spikes with single coil spring washers for anchors
11	59	47	47	153 2 cut spikes for line and 2 round head Dowel Studs with double coil helical spring washers for anchors
12	57	48	48	153 2 cut spikes for line and 2 Oliver Hold-Down Drive Spikes with double coil helical spring washers for anchors
12	2	0	0	2 2 cut spikes for line and 2 cone neck type Oliver Hold-Down Drive Spikes without spring washers for anchors
13	47	47	47	141 2 cut spikes for line and 2 Elastic Spikes of design No. 93 for anchors
13	12	0	0	12 2 cut spikes for line and 2 Tie Plate Lock Spikes for anchors
14	47	24	24	95 2 cut spikes for line and 2-3/4 in. thru bolts with single coil spring washers for anchors (Applied in the field)
15	48	24	24	96 2 cut spikes for line and 2-3/4 in. thru bolts with single coil spring washers for anchors (Applied in shop under load)
(a)16	60	47	48	155 2 cut spikes for line and 2 screw spikes with double coil spring washers for anchors
17	60	47	47	154 2 AAR spring rail clips and screw spikes for line and anchor spikes on tangent plus 2 cut spikes for line on the curve
18	58	48	48	154 No anchor spikes. Erie RR. standard 13 in. single shoulder tie plate with diamond bottom
(a)19	59	0	0	59 2 cut spikes for line and 2 screw spikes with double coil spring washers for anchors using above Erie RR. tie plate
20	0	47	47	94 2 Thompson Rail and Tie Plate Clamps with screw spikes and triple coil spring washers for line and anchor spikes on tangent
21	0	47	47	94 Fabreeka SA-47 Track Pads, 1/4 in. thick, no anchor spikes
22	0	48	48	96 2 cut spikes for line and 2 Oliver Tie Plate Drive Spikes with single coil Spring washers for anchors
23	24	24	23	71 L. & N. RR. Standard 14 in. tie plate with 2 each of cut spikes for line and anchors
24	24	24	24	72 L. & N. RR. Standard 14 in. tie plate with 2 each of cut spikes for line and anchors and a Rails Co. clip on alternate tie plates
	1012	884	901	2797 Totals

Notes: AREA Plan 5B (Modified) 13 in. tie plate with flat rail seat was used in all sections except as follows: (1) Penn. RR. standard 14-3/4 in. tie plate cut to a length of 13 in. for section 17; (2) Erie RR. standard 13 in. single shoulder, diamond bottom tie plate for sections 18 and 19; (3) L. & N. RR. standard 14 in. tie plate for sections 23 and 24.
In the sections on the curve where no anchor spikes were provided, 4 9/16 in. × 5½ in. cut spikes per tie plate were used as line spikes.
(a) In the north half of each portion of these test sections the double coil Helical (experimental) spring washer was used and in the south half the double coil Thackery washer was used.

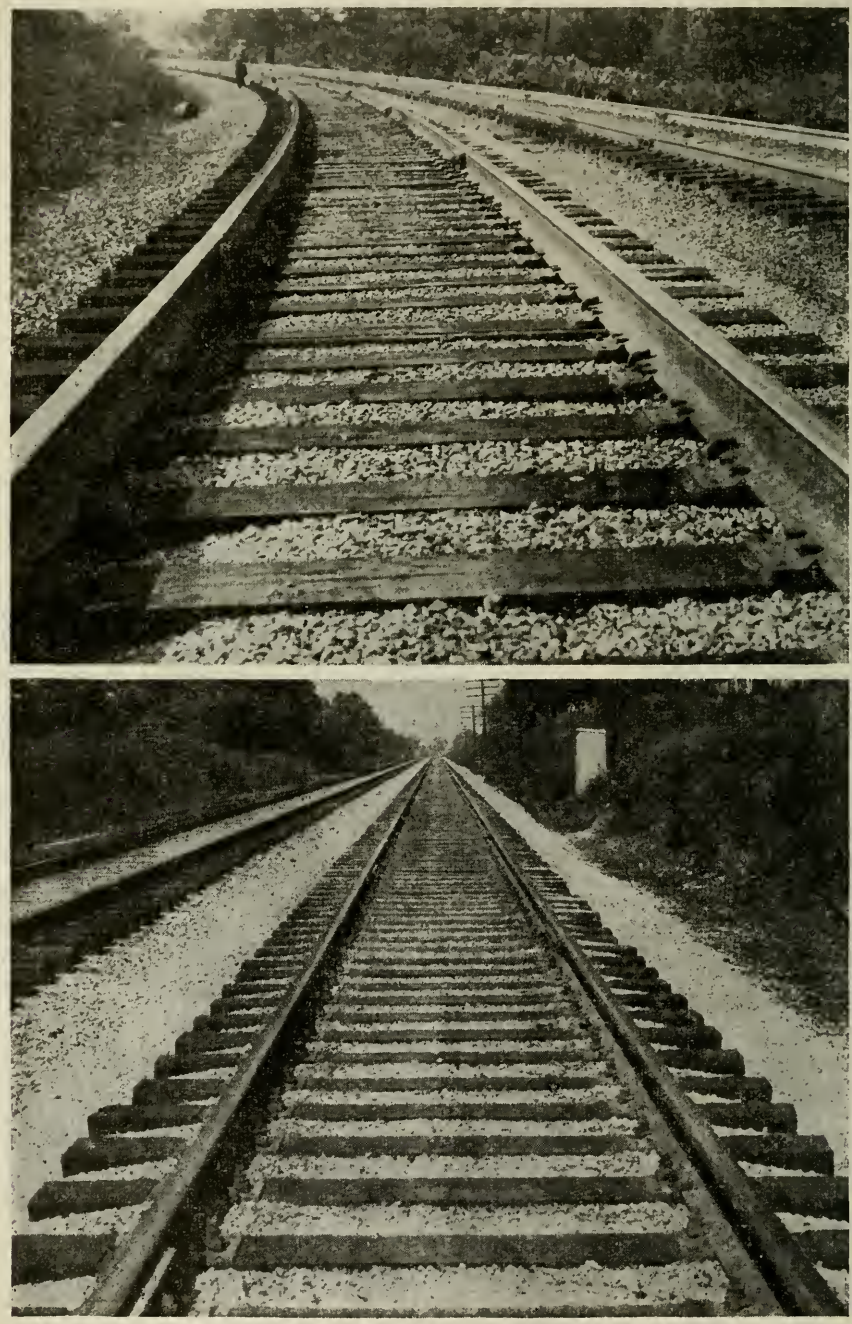


Fig. 2.—General Views of Test Track.

Test Installation on the Louisville & Nashville

The Louisville & Nashville Railroad through L. L. Adams, assistant chief engineer, kindly agreed to install the test sections on a cooperative basis in the northward main track near London, Ky. The Association of American Railroads furnished all of the tie plates (except the 14-in. length) and the hold-down fastenings, and the railroad furnished all labor and other material, which included about 2800 new 7-in. by 8-in. and 7-in. by 9-in., 8 ft. 6 in. long creosoted oak and pine ties, new stone ballast of 1½-in. maximum size, standard fastenings and a general surfacing of the track which consisted of two lifts, the first being fork tamped and the second power tamped.

The test installation was made in miles L-154 and L-155 as shown in the upper portion of Fig. 1. The 4-deg. 30-min. curve test location was separated from the tangent test location by a short curve of the same degree but in the opposite direction. The test curve is on a summit with a grade of 0.50-percent descending each way; the tangent section is on a 0.65-percent grade ascending against the traffic. The northward main carries 25 million gross tons of traffic per annum, consisting largely of loaded coal cars and hauled by moderately large 2–8–4 and 2–8–2 type locomotives, which are double-headed on most of the coal trains. The 4-deg. 30-min. test curve has 5 in. elevation and is restricted to 45 and 35 mph. for passenger and freight trains, respectively. The authorized speeds for the operating district are 60 and 45 mph. for passenger and freight trains but the prevailing speeds on the test tangent are lower because of the restriction at the curve. Some of the heavy freight trains operate at speeds as low as 20 mph. on the test curve.

The northward main track is laid with 131-lb. RE rail, 24 ties to the panel and 10 forward anchors per rail. The test curve has 1940 rail on the outside and relay rail laid in 1947 on the inside, with 4-hole head contact joint bars, and the tangent section has 1944 rail with 6-hole head contact joint bars. The test curve is protected by a rail oiler.

The location of the 24 individual test sections is given in Fig. 1, and a description of the construction for each of these is tabulated in Table 1. Most of the construction work was performed in August 1947, and the sections requiring assembly before insertion as well as the six panels of L. & N. standard construction were placed in September. Two general views of the test track are shown in Fig. 2.

Initial readings for measurement of mechanical wear of ties, variation in track gage, curvature and cross levels were completed in November 1947. It is proposed to repeat the measurements for gage of track on the curve and make an inspection each year. Because the tie plate penetration amounts to very little while the ties are new, all other measurements will be repeated at longer intervals, perhaps every two or three years.

When the first progress report is presented a full description of the types of construction will be included.

All of the construction work was performed by section forces of the L. & N. under the direct supervision of H. E. Durham, track engineer, Research Staff, AAR, and at the general direction of G. M. Magee, research engineer.

The committee is indebted to the railroad for its contribution of labor and material for the test track and the high standard of work performed. Also the committee is indebted to the suppliers of the hold-down fastenings, pads, etc., for their cooperation in donating the material in many instances and for many other services such as expediting the manufacture and delivery of the material, and assistance in other ways.

Tests on Illinois Central

Last year your committee presented the first progress report covering a service test of several types of hold-down fastenings in the Illinois Central System's main tracks 2 and 3 in miles 43, 44 and 45, north of Manteno, Ill. The test data for 1947 showed very little additional mechanical wear of ties, and publication of the results will therefore be omitted this year. It is proposed to continue to check the tie plate penetration annually, but to report the results at less frequent intervals.

Report on Assignment 9

Recommendations on Number and Placing of Anti-Creepers for Various Conditions

E. E. Martin (chairman, subcommittee), L. L. Adams, J. C. Aker, W. G. Arn, A. L. Bartlett, T. H. Beebe, H. J. Bogardus, A. E. Botts, E. J. Brown, M. D. Carothers, W. E. Cornell, B. E. Crumpler, H. F. Fifield, J. W. Fulmer, A. B. Hillman, J. P. Hiltz, T. R. Klingel, G. M. Magee, M. K. Ruppert, R. R. Smith, Troy West.

Your committee submits its fourth and final progress report as information, together with recommendations as to number and position of rail anchors for adoption and publication in the Manual. These recommendations are based upon measurements and observations over a period of four years of three service tests of rail anchoring, including various arrangements of anchorage in both crushed rock and gravel ballast; as well as one way and two way traffic.

Rail Anchorage Test on the Chicago, Milwaukee, St. Paul & Pacific Railroad Near Mauston, Wis.

This test installation is located in the westward main track of the Milwaukee Road between M.P. 203 and 212 near Mauston, Wis. The track is constructed of 131-lb. RE rail, 4-hole joint bars, 24 ties to the panel and gravel ballast containing a large proportion of sand. This track carries 8 passenger trains and approximately 5 freight trains daily.

Discussion of Test Data

Rail Creepage

Rail creepage measurements as taken from reference stakes set at ⅛-mile intervals are shown in Fig. 1 for the past year for the nine test miles. This figure shows the present arrangement of anchors in a panel of track, and it will be observed that in all miles except 211 and 212 having methods H and I, respectively, the original arrangements have been abandoned because of unsatisfactory performance. Previously, the methods used in miles 204, 206 and 207 were changed to arrangement I and omitted from the test except for the rail creepage data. According to the amount of creepage for the past year, the existing anchorage methods in all of the nine miles are adequately arresting rail creepage.

Test Section I–2

In mile 205 method I–2 was installed in March 1946 to determine the merits of "boxing in" the back-up anchors instead of placing them against adjacent ties. The last inspection of this section showed no indication of the boxed anchored ties churning in

Previous reports covering these tests may be found in the Proceedings, Vol. 45, 1944, pages 373–376; Vol. 46, 1945, pages 569–592; Vol. 47, 1946, pages 527–545 and Vol. 48, 1947, pages 619–634.

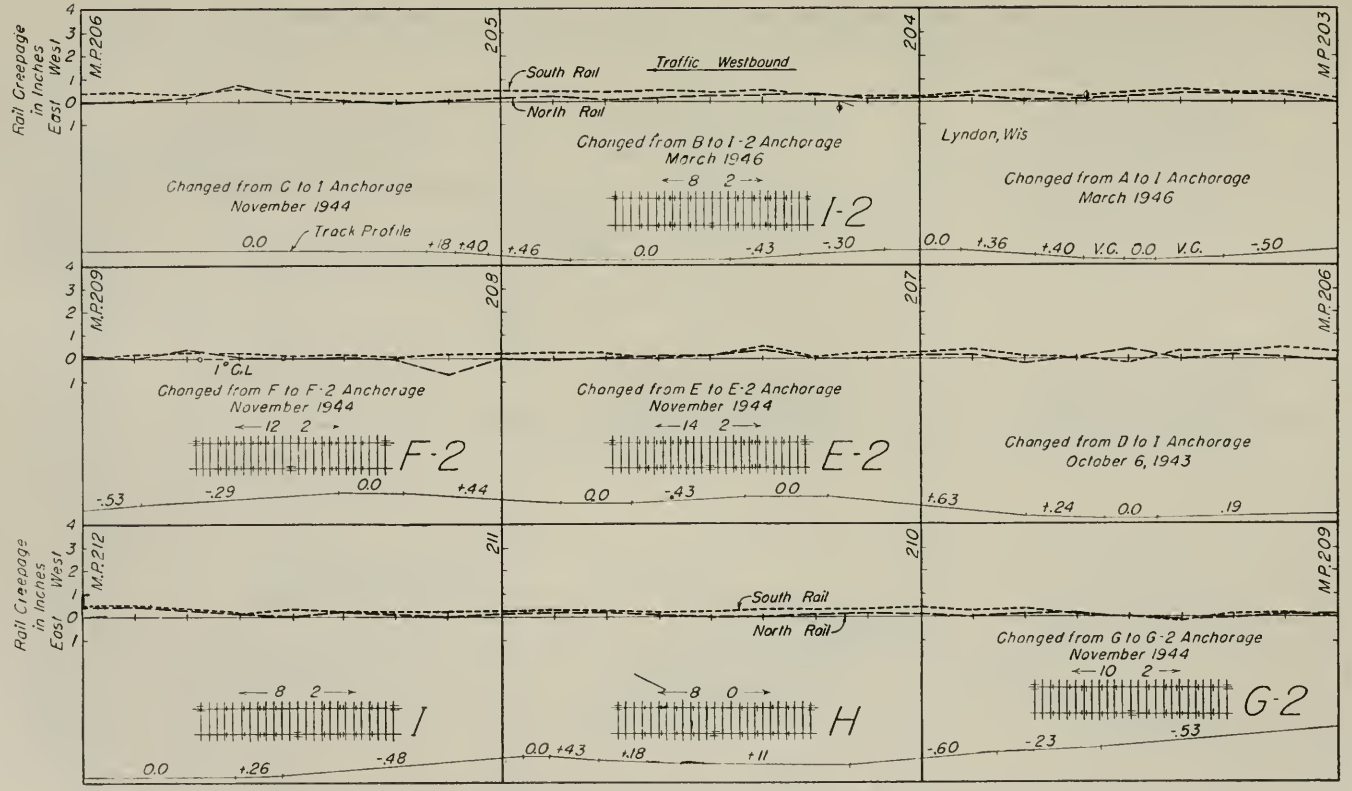


Fig. 1.—Rail Creepage, June 1946 to July 1947, C. M. St. P. & P., Westbound Track, Lyndon to Mauston, Wis.

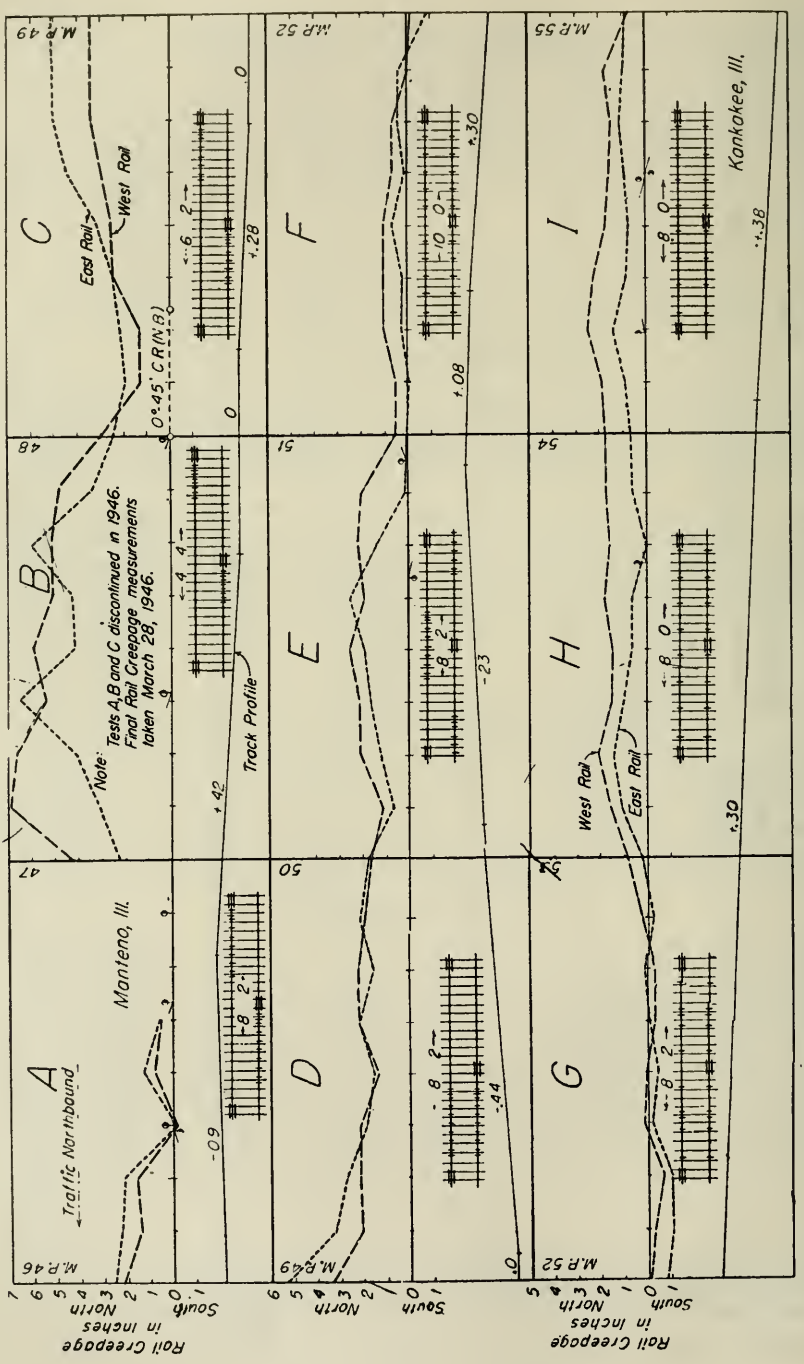


Fig. 2.—Rail Creepage, October 1943 to June 1947, Illinois Central, Northbound Track, Kankakee to Manteno, Ill.

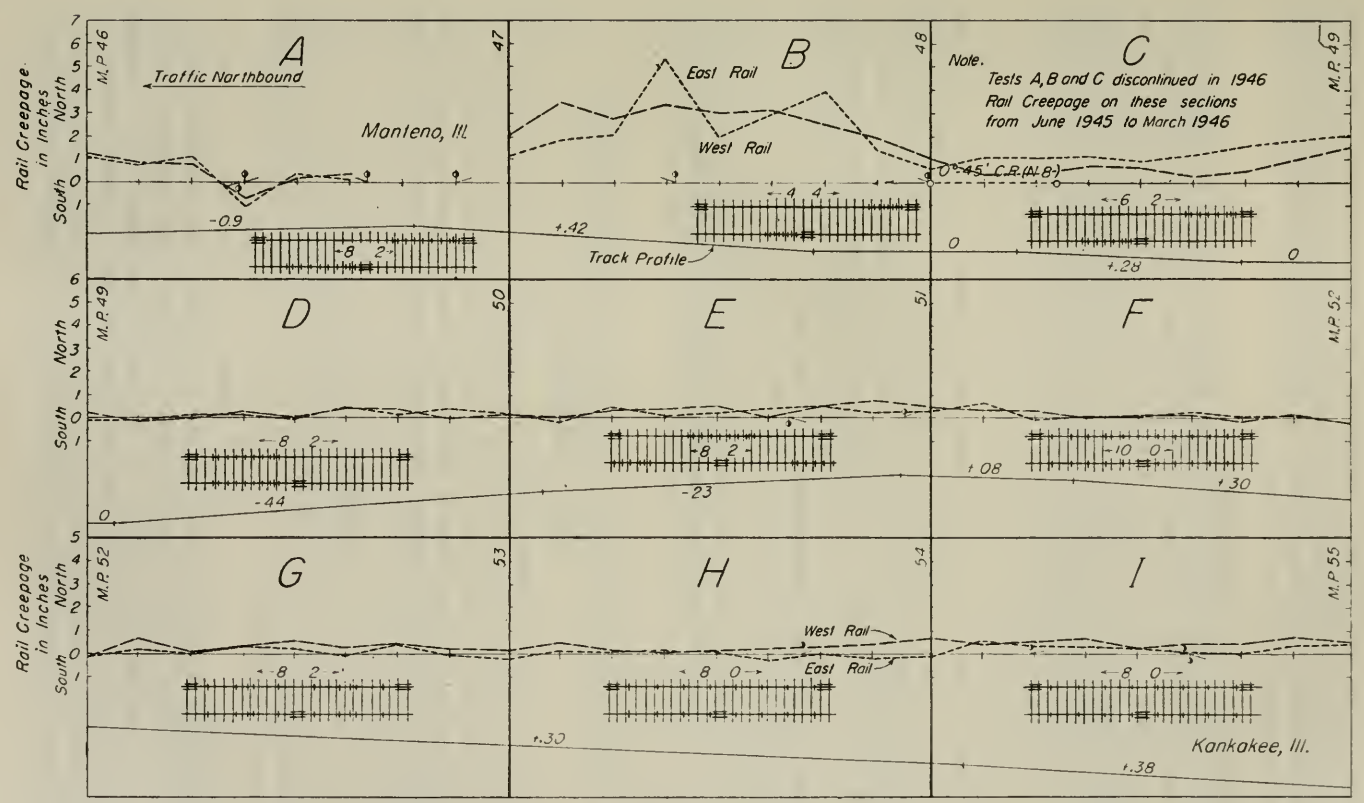


Fig. 3.—Rail Creepage, June 1946 to June 1947, Illinois Central, Northbound Track, Kankakee to Manteno, Ill.

the ballast and the rail creepage for the past year was moderate in amount. This method has the advantage of maintaining the back-up anchors in constant contact with the tie, whereas in method I the back-up anchors are moved away from the ties by the amount of rail creepage in the direction of traffic.

Test Sections E–2, F–2 and G–2

These methods have been in service since November 1944 and the rail creepage in miles 208, 209 and 210 for the past year was very small. However, the performance of methods E–2, F–2 and G–2 with 14, 12, and 10 forward anchors respectively, was not a sufficient improvement over the performance of arrangements H and I with 8 forward anchors to justify the added number of anchors. In methods E–2 and G–2 the boxed anchored ties showed no indication of a churning movement. In method F–2 the back-up anchors which were not boxed were about 1 in. away from the ties.

Test Sections H and I

Methods H and I continued to show good performance and the rail movement during the past year was small. Each of these test miles has 8 forward anchors per rail and, in addition, method I has two back-up anchors not boxed. The back-up anchors were observed to be 1 in. to 2 in. away from the ties in method I and, of course, are not effective in restraining the rail creepage for an occasional movement against the current of traffic, or when a joint is pulled in two, until the rail has moved eastward sufficiently to engage the back-up anchors with the ties.

Joint Gaps

Joint gap measurements were made when the rail temperature ranged from 87 to 100 deg. F. The results were not appreciably different from those shown in previous reports and there was no apparent superiority in uniformity of joint gap for any of the methods of anchorage.

Rail Anchorage Test on the Illinois Central Railroad Near Kankakee, Ill.

This test is in the northward main (No. 3) of the three-track main line of the Illinois Central Railroad between Kankakee and Manteno, Ill., which carries traffic in only one direction but differs from the Milwaukee Road test near Mauston, Wis., in that moderately coarse stone ballast is used instead of gravel, except that mile 55 which is largely in yard limits is ballasted with cinders. The track is laid with 112-lb. RE rail and 4-hole joint bars.

Discussion of Test Data

As stated in last year's report sections A, B and C on miles 46, 47 and 48 were discontinued March 28, 1946, because of tie skewing which adversely affected the line and the gage of the track.

Rail Creepage

Rail creepage for the six miles continued in this test for the period from October 1943 to June 1947 as shown in Fig. 2, and Fig. 3 gives corresponding information for the period from June 1946 to June 1947. The total rail movement (Fig. 2) continued to be the smallest in sections F and G. During the last year all methods except A, B and C, which were discontinued, showed very little rail creepage. The 10 forward anchors used in method F showed only a slight superiority over the methods using 8 forward anchors.

Joint Gaps

Joint gap measurements were repeated in June 1947; the results obtained were substantially the same as previously reported.

Rail Anchorage Test on the Chicago, Milwaukee, St. Paul & Pacific Railroad Between Burlington and Kansasville, Wis.

This test installation is in the single-track main line of the Milwaukee Road between Burlington and Kansasville, Wis., and is the only test where the traffic is in both directions. The track is constructed of 112-lb. RE rail with 4-hole joint bars, 24 ties to the panel, and gravel ballast containing a large proportion of fine material. The traffic consists of two passenger trains and approximately three freight trains each way daily.

Discussion of Test Data

Rail Creepage

In Fig. 4 the rail creepage is shown in each of the nine test miles for the total test period from November 1943 to June 1947, and corresponding information is shown in Fig. 5 for the 11-month period ended June 1947.

The initial methods which provided anchorage principally for one direction of traffic did not give satisfactory performance and were modified to provide anchorage in both directions. As a result, the performance of all sections was reasonably good during the past year with the exception of a portion of mile 25 and this is probably due to the fact that the ties had just been respaced and anchors rearranged in July 1946.

Joint Gaps

Joint gap measurements were made in June 1947. The rail temperature ranged from 53 to 77 deg. F. There were no significant differences in the uniformity of the joint gap width in the eight test miles reported.

Observation of Tie Movement

Churning of anchored ties and occasionally an excessive movement of an unanchored tie as a result of a ratchet-like action of the rail base in the tie plate seat accompanying the back-and-forth creepage of the rail have been important factors in this single-track test installation. In mile 18, with anchorage method F–2 since May 1946, some of the anchored ties showed evidence of churning in the ballast. Generally, these were the ties that were respaced in May 1946. Last year's rail creepage in this mile was of moderate amount.

In mile 19 with method B anchorage the anchored ties were skewed badly and unanchored ties were bunched in a number of places.

Mile 20 has anchorage method F in the east half and arrangement C in the west half. The boxed anchored ties in method F showed evidence of considerable churning. The anchored ties with method C anchorage were badly skewed and bunched.

There was very little evidence of tie movement in mile 21 with method D. Some of the anchored ties were skewed because of the rails creeping in opposite directions.

In mile 22 with method E the anchored ties were skewed, having pivoted around the unanchored end.

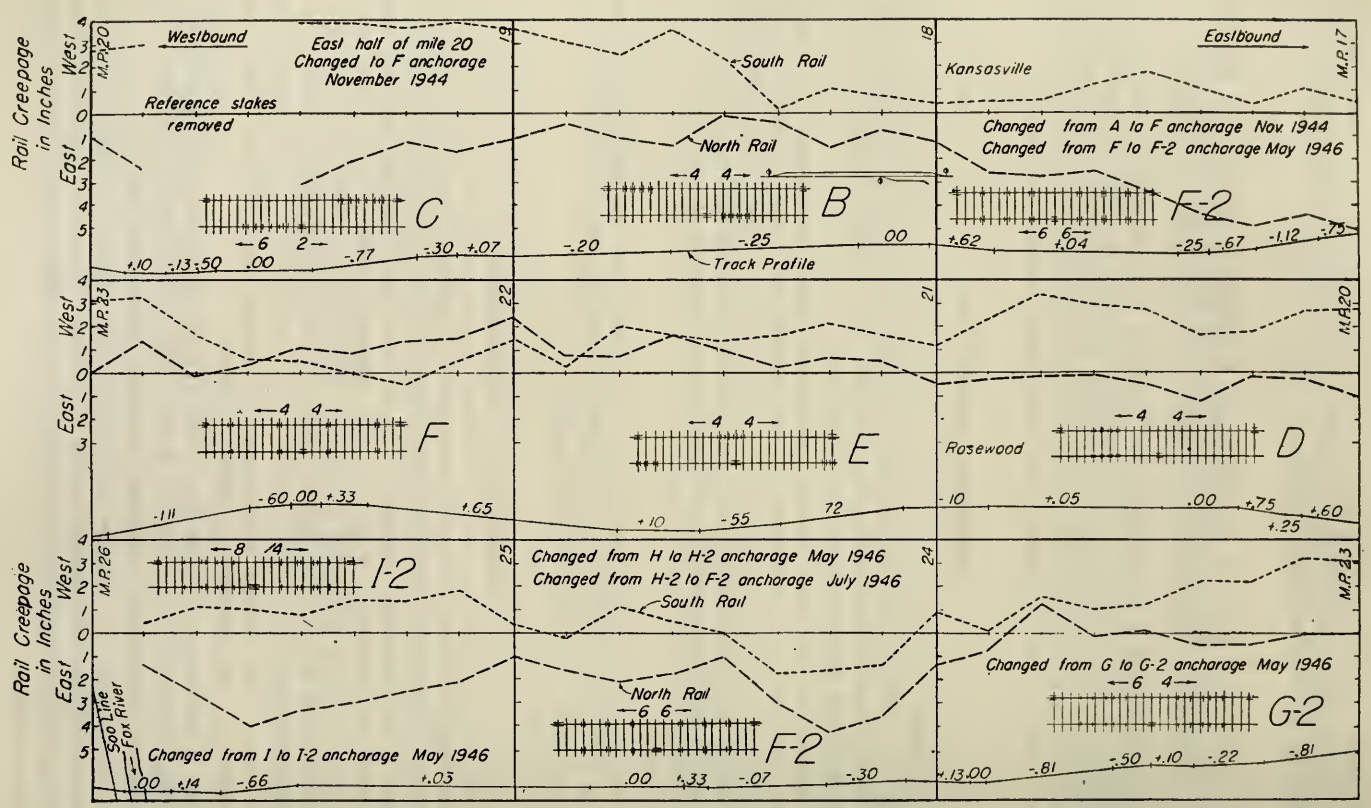


Fig. 4.—Rail Creepage, November 1943 to June 1947. C. M. St. P. & P., Burlington to Kansasville, Wis.

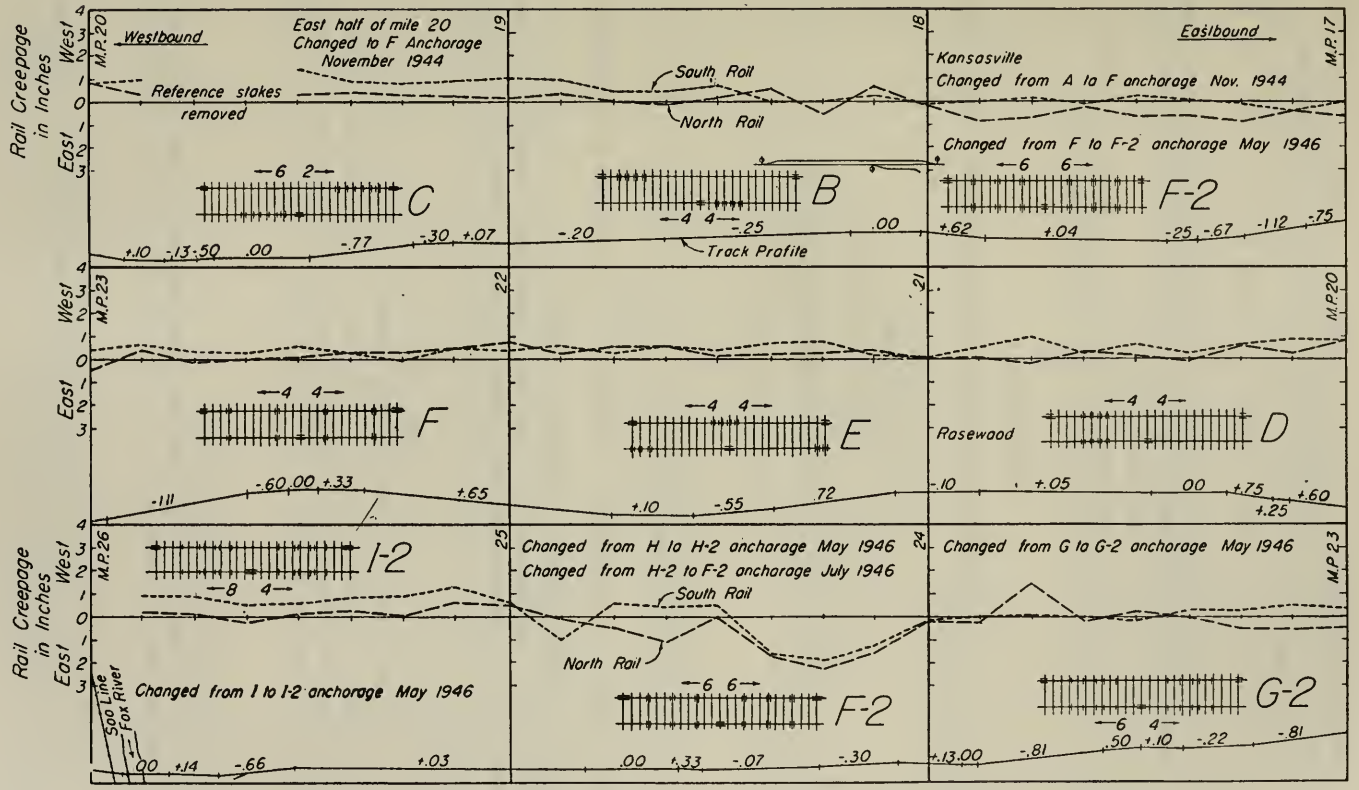


Fig. 5.—Rail Creepage, July 1946 to June 1947. C. M. St. P. & P., Burlington to Kansasville, Wis.

Considerable churning of the anchored ties in the east and west quarters of mile 23 with method F was in evidence. The middle half of this mile was in good condition.

There was evidence of ties churning in the east ¼ and west ⅛ of mile 24 with anchorage method G–2 and some of the ties were more than 6 in. away from the anchors.

The anchorage was changed from H to H–2 and from H–2 to F–2 in 1946 on mile 25 and because of loose ballast resulting from the respacing of ties there was considerable evidence of churning of the boxed anchored ties.

In mile 26, in which anchorage method I–2 was adopted in May 1946, a number of anchors set to resist eastward movement of the rail were away from the ties.

Conclusions

Your committee recommends that the matter on page 5–18 of the Manual, reading as follows be withdrawn:

ANTI-CREEPERS

1936

The use of anti-creepers to prevent longitudinal movement of rail in track is recommended.

It is also recommended that in place of the above, the following recommendations be adopted and published in the Manual:

RAIL CREEPAGE—NUMBER AND POSITION OF RAIL ANCHORS

Track with Essentially One Direction of Traffic

With very few exceptions, rail creepage is in the direction of traffic. The amount of creepage will vary with the kind of ballast used and with local conditions. A minimum of 8 anchors per 39-ft. rail length is required. Additional anchors should be used where needed.

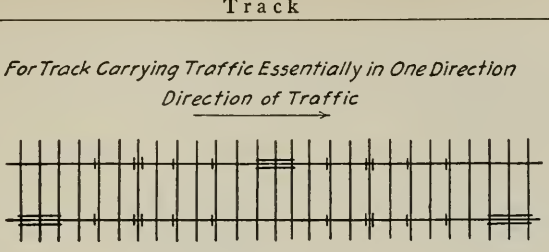
Rail anchors should be spaced approximately uniformly along the rail length. To avoid tie skewing, the anchors should be applied against the same tie on opposite rails.

To provide for occasional reversal of traffic and to prevent excessive opening in case of a broken rail, at least 2 back-up anchors should also be applied per rail length and boxed in around the tie with 2 of the forward anchors near the quarter points of the rail.

Track with Traffic in Both Directions

Effective anchorage to minimize back and forth movement of the rail occurring during train movements in opposite directions, is necessary to prevent tie churning and bunched ties.

The use of 16 rail anchors per 39-ft. rail length is recommended; 8 to resist movement in each direction for balanced traffic. If the traffic is much lighter in one direction, the number of anchors used to resist movement in that direction may be reduced. Additional anchors should be used where needed.


For Track Carrying Traffic Essentially in One Direction
Direction of Traffic
For Average Conditions -
any type of ballast
8 forward anchors and 2 back up anchors per 39 ft. rail length
For Track Carrying Traffic in Both Directions
Direction of Traffic
For Average Conditions -
any type of ballast
16 anchors per 39 ft. rail length
8 anchors placed to resist movement in each direction

Recommended Rail Anchorage.

The rail anchors should be spaced approximately uniformly along the rail length and against the same tie on opposite rails. The anchors to resist movement in the two directions should be placed in pairs and boxed around the same tie.

The arrangement of rail anchors for both one and two directional traffic is indicated in the diagram. It is important that the anchors be carefully applied and that they be in contact and remain in contact with the tie face.

Report of Committee 4—Rail

C. B. Bronson, *Chairman,*
J. B. Akers
J. E. Armstrong
S. E. Armstrong
H. Austill
W. C. Barnes
C. H. Blackman
W. J. Burton
E. E. Chapman
C. M. Chumley
H. R. Clarke
C. J. Code
L. S. Crane
P. O. Ferris
J. L. Gressitt
G. F. Hand
G. W. Harris
C. B. Harveson
E. M. Hastings
F. S. Hewes
S. R. Hursh
Maro Johnson
F. R. Layng
H. S. Loeffler
G. M. Magee
E. E. Mayo
Ray McBrian
R. J. Middleton
C. E. Morgan
R. A. Morrison
E. E. Oviatt
R. E. Patterson
W. H. Penfield
W. C. Perkins
L. T. Nuckols, *Vice-Chairman,*
G. A. Phillips
J. G. Roney
J. C. Ryan
E. F. Salisbury
R. T. Scholes
I. H. Schram
F. S. Schwinn
W. D. Simpson
G. L. Smith
F. W. Thompson
E. C. Vandenburgh
J. C. Wallace
Barton Wheelwright
R. P. Winton
J. G. Wishart

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including revisions recommended for adoption and publication ..... page 375

2. Research on conditions affecting service life of rail, and the causes of rail failures and other defects, in collaboration with the AISI Technical Committee on Rail and Joint Bars.

   Progress report, presenting fourteenth progress report of the rails investigation ..... page 490

3. Compilation of statistics.
   (a) All rail failures, making special study of transverse fissure failures.
   (b) Determine the performance of control cooled and brunorized rail in service with respect to rail failures.

   Progress report on entire assignment, presented as information ..... page 383

4. Methods of hardening rail ends and reconditioning them to control rail battering.

   Progress report, including recommendations for adoption and publication in the Manual ..... page 398

5. Economic value of different sizes of rail.

   No report.

6. Continuous welded rail, collaborating with Committee 5.

   Progress report, presented as information ..... page 404

AREA Bulletin 472, February 1948.

7. Service tests of various types of joint bars.
Final report, presented as information ..... page 405

8. Joint bar wear and failures; revision of design and specification for new bars and bars for maintenance repairs.

Appendix 8-a, sixth progress report of the rolling-load tests of joint bars, presented as information ..... page 416

9. Corrugated rail—causes and remedy. Effect upon riding qualities of tracks and upon the costs of track and equipment maintenance.

Progress report, presented as information ..... page 426

Appendix 9–a—third progress report on corrugated rails ..... page 428

10. Development and characteristics of fractures under engine burns in rail, together with investigation as to the effectiveness of welding up engine burns by oxyacetylene or electric methods.
Progress report, presented as information ..... page 429

Appendix 10–a—Progress report of rolling-load tests on engine-burned rails ..... page 430

11. Causes of shelly spots and head checks in rail surfaces; develop measures for their prevention.

Progress report, presented as information ..... page 434

Appendix 11-a, report of field investigation by the research staff ..... page 437

Appendix 11-b, sixth progress report of the shelly rail studies at the University of Illinois ..... page 437

Appendix 11-c, progress report of the shelly rail studies at the Battelle Memorial Institute ..... page 446

12. Recent developments affecting rail section.

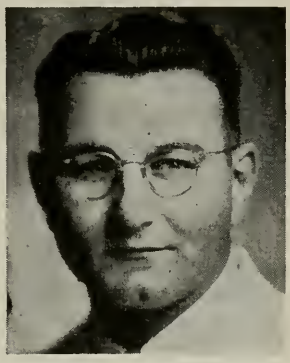
Progress report, presented as information ..... page 464

Appendix 12-a, effect of bolt hole spacing on rail web stresses within the rail joint ..... page 464

Appendix 12-b, report of fatigue tests of rail webs at the University of Illinois ..... page 485

The Committee on Rail,
C. B. Bronson, *Chairman.*

Norville J. Alleman



It was with deep regret that the Rail Committee received the news of the untimely passing of Professor Norville J. Alleman at Champaign, Ill., on July 13, 1947.

Professor Alleman had been associated since 1932 with the Rail Committee's research on railroad rails and joint bars carried on at the laboratories of the University of Illinois. His work contributed materially to the success of these investigations and his valuable help will be greatly missed by this committee.

Report on Assignment 1

Revision of Manual

L. T. Nuckols (chairman, subcommittee), J. E. Armstrong, H. Austill, W. C. Barnes, C. H. Blackman, C. B. Bronson, W. J. Burton, J. L. Gressitt, G. F. Hand, G. W. Harris, E. M. Hastings, F. S. Hewes, Maro Johnson, F. R. Layng, G. M. Magee, R. J. Middleton, E. E. Oviatt, E. F. Salisbury, G. L. Smith, E. C. Vandenburgh, J. C. Wallace, Barton Wheelwright.

Your committee recommends the inclusion, revision, deletion, or reapproval of the following items in the Manual:

Pages 4–7 and 4–8 (Figs. 1 and 2)

90-lb. RA–A and 100-lb. RE Rail Sections

1915

Submitted for reapproval without change.

Page 4–12

Application of Welded Bonds

1930

Delete existing subject matter and substitute the following:

The application of pin connected bonds or welded bonds to the outer side of rail head, within the limits of the joint bars for standard bonding and outside of joint bars for special work where not practicable to apply them within the joint bar limits, is good practice.

Pages 4–25 and 4–26

Joint Bars for 90-lb. RA–A and 100-lb. RE Rail
1936

Submitted for reapproval without change.

Page 4–28.5

Respacing of Bolt Hole Drilling in Rails and Corresponding Bar Punching

On recommendation of the Committee on Rail and with the approval of the Board of Direction, a letter ballot was issued to the membership on November 1, 1947, submitting for adoption a rail drilling and joint bar spacing for 115-lb., 132-lb. and 133-lb. RE rail sections.

The letter of transmittal to the members which appeared in the AREA News for November 1947, the ballot and the report of the tellers are reproduced below. Approval of this proposition by the Association of American Railroads became effective on November 18, 1947.

Letter Ballot on Change in Rail Drilling

To the Members:

For all voting members, there is enclosed a letter ballot authorized by the Board of Direction on the recommendation of the Committee on Rail. In this ballot you are asked to approve or disapprove a revision of the table on page 4-28.5 of the Manual to change the drilling of 115-lb., 132-lb. and 133-lb. RE rail (and the punching of corresponding joint bars) as follows:

Spacing of Bolt Holes from Rail End
(in inches)

Present	Proposed
Six-Hole Joints	
2½—6½—6½	3½—6—6
Four-Hole Joints	
2½—6½	3½—6

The reason for requesting immediate approval is to insure that this matter will be settled in ample time to get the new drilling specified in rail purchased for 1948 delivery. While some railroads have already laid 115, 132 and 133-lb. RE rail, many of them expect to lay rail of these sections for the first time next year and it is desired to apply the new drilling to their initial purchases of rail in the new sections to avoid the disadvantages of having in track two different drillings of the same rail section.

The Committee on Rail has become convinced of the desirability of the change in the spacing of the bolt holes in rail joints as the result of an investigation carried out during the last year under the assignment, Investigate recent developments affecting rail design.

Nature of the Investigation

Tests were conducted in the laboratory at the University of Illinois to study the effect of bolt tension, applied wheel loads and bolt hole spacing upon rail web stresses within the limits of the joint bar. Tests were made with bolt tensions of 10,000 lb., 20,000 lb. and 30,000 lb. The wheel loads were applied so as to produce reverse

flexure of the rail joint corresponding to that under traffic, and also introduce eccentric loading. Three bolt spacings from the rail end were used as follows: (A) The present AREA drilling of 2½ in.—6½ in.—6½ in.; (B) 3½ in.—6 in.—6 in.; and (C) 4½ in.—5½ in.—5½ in. The rail used was the new 115-lb. RE section with 36 in. headfree joint bars and 1-in. diameter bolts.

Field stress measurements—during the passage of regular trains—were made on 131-lb. RE rail with 6-hole, 36 in. headfree joints to determine the range of stress in the web at and around the bolt holes and in the upper and lower fillets at and near the end of the rail.

Results Obtained

The results of these field and laboratory tests may be summarized as follows:

Bolt tightening had a pronounced effect in producing tensile stresses in the rail web in a vertical direction.

The stresses around bolt holes are three times as high as elsewhere in the web due to the stress concentrating effect of the holes.

High tensile stresses were found also in the upper and lower fillets near the rail ends.

Moving the first hole farther away from the rail end not only lowered the tensile stresses around the bolt hole but also reduced the stresses in the upper and lower fillets near the rail end. For the proposed new drilling, the reduction in the intensity of stress around the first hole amounts to 25 percent, while the reduction in the upper fillet stress is 32 percent. As is well known, service cracks have occurred at both of these locations with some frequency.

Also, in laboratory fatigue tests in which the rails were subjected to reverse flexure similar to that encountered in service, it was found that the joint bars with the proposed drilling developed a fatigue life 27 percent longer than for joints with the present drilling.

The proposed drilling (with holes farther from the rail end) developed no appreciable adverse effect with respect to rail end batter or joint deflection.

Conclusion

Accordingly, it is the conclusion of the Committee on Rail that the proposed drilling will result in a substantial improvement in rail joint service. The committee's recommendation for the adoption of the proposed drilling was ratified by a vote well in excess of two-thirds of the committee membership. Its recommendation that the proposal be submitted to the membership by letter ballot has received the sanction of the Board of Direction. Please return your vote by November 17, 1947.

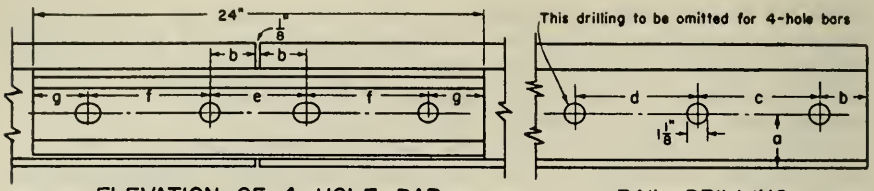
W. S. Lacher,
Secretary.

American Railway Engineering Association

LETTER BALLOT

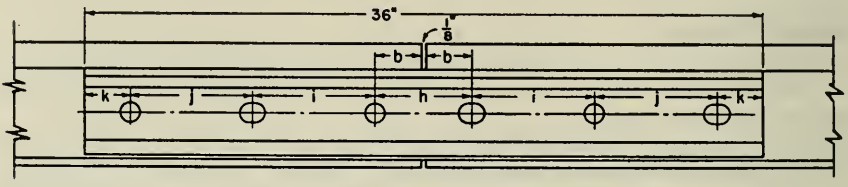
W. S. Lacher
Secretary, AREA

I approve ☐ the recommendation of the Committee on Rail to revise the Table of
I disapprove ☐ Recommended Rail Drillings, Bar Punchings and Track Bolts on page 4-28.5 of the Manual so that the following dimensions as relating to the position of bolt holes of 115-lb., 132-lb. and 133-lb. RE rail and joint bars would be revised as indicated below:



ELEVATION OF 4 HOLE BAR

RAIL DRILLING



ELEVATION OF 6 HOLE BAR

Dimensions	*Present inches*	*Proposed inches*
b	2½	3½
c, d, f, i and j	6½	6
e and h	5⅛	7⅛
g	2 15/16	2 7/16

The effect of these changes in dimensions would revise the bolt rail drillings in these three sections of rail from 2½ in.–6½ in.–6½ in. to 3½ in.–6 in.–6 in. for six hole joints and from 2½ in.–6½ in. to 3½ in.–6 in. for four-hole joints.

Report of the Tellers

We, the Committee of Tellers, appointed to canvass the ballots issued November 1, 1947, on the proposed change in the "drilling" (position of bolt holes) in 115-lb., 132-lb. and 133-lb. RE rail and joint bars as provided for on page 4-28.5 of the Manual find that the count of the ballots is as follows:

In favor of the proposed change	685
Opposed to the proposed change	46

(Signed) C. W. Breed
J. S. Knight
C. T. Jackson
H. F. Whitehead
G. M. Strachan
(Committee of Tellers)

Pages 4–37 and 4–38

Specification for Spring Washers
1933

Delete the present table of reactive pressures and substitute the following table. Delete the italicized note just below the existing table.

Spring Washers for Bolt Dia. in.	*Applied Load lb.*	*Platens Released from Loads by Distances in.*	*Minimum Reactive Spring Pressure lb.*
3/4	20,000	0.025	2500
7/8	20,000	0.025	2500
1	20,000	0.030	5000
1-1/16	20,000	0.030	5000
1-1/8	20,000	0.030	5000

Page 4–46

Add the following to the Description of Rail Failures on Form 402–A, and also to the Glossary of the Manual:

TRANSVERSE DEFECT.—For defects found by detector cars, a tentative group classification, applied prior to the breaking of the rails, of all types of rail defects which have transverse components, such as transverse fissures (TF), compound fissures (CF), and detail fractures (DF).

Pages 4–47 to 4–50, incl.

Rail Failure Form 402–C, 402–C (a) and 402–L 1946

Delete the above forms and substitute the forms bearing the same designations printed elsewhere in this report.

Form 402–C (a)
Rev. 1948

ASSOCIATION OF AMERICAN RAILROADS

Engineering Division

Instructions for filling in Rail Failure Forms 402–C, Rev. 1948, and 402–L, Rev. 1948.

FORM 402–C

1. Statistics are desired for all new CONTROL COOLED RAIL ONLY weighing 80 lb. per yd. and over, laid in all main tracks. Continue records 10 years unless rail has been removed from main tracks where originally laid. Omit information for rollings of less than 500 tons. DO NOT REPORT rails removed from track on account of wear, battered or chipped ends, broken or damaged by wheel burns or other external causes, unless detail fractures have developed.
2. Since former reports rendered on Form 402–C, Rev. 1946, combined detail fractures and engine burn fractures with compound fissures, and also vertical split heads with horizontal split heads, the accumulated totals for the current year to be listed on the 1948 revision of that form cannot be obtained in the usual manner by adding the current year's failures to the accumulated total reported for the preceding year. It will be necessary to derive new totals from your past records of control cooled rail only, segregated as called for by the new column headings.
3. It is difficult for detector car operators to distinguish the difference between transverse fissures, compound fissures and detail fractures for the reason that all of these types have vertical components and most of the defects are hidden within the rail head. Many of these in the past have been improperly classified by the operators for this reason. The operators are reporting such types of detected failures under the group classification "Transverse Defects" abbreviated "T.D." and it is up to the railroad to determine the type for each rail by breaking the same for visual examination and proper classification. All failures tentatively classified as Transverse Fissures by visual inspection after breaking are subject to laboratory investigation and final verification as provided for in Instruction No. 4. List those that are so verified in column headed "Trans. Fiss. Ver. by U. of I." In case specimens of failures tentatively classified as transverse fissures are lost in shipment or otherwise unavailable for laboratory verification, such failures should be reported in column headed "Comp. Fiss. & Det. Frac."

ASSOCIATION OF AMERICAN RAILROADS

Form 402-C

ENGINEERING DIVISION

Rev. 1948

CC Rail Failures Only for Year Ending December 31, 19... Railroad ..... Sheet No. of

Mill & Kind of Steel	Year Rolled and Yr. Laid	Section and lb. per yd.	Gross Tons New Rail Laid	Equiv. Track Miles	Mile-Years	Period	Trans. Fiss. Ver. by U. of I.		*Comp. Fiss. & Det. Frac.	V.S.H.	H.S.H.	Other Head	Broken	Web		Base	All Types	**Engine Burn Frac.
							Serv.	Det.	Total	Total	Total	Total	Total	In Joint	Other	Total	Total	Total
						This Yr. Total												
						This Yr. Total												
						This Yr. Total												
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In filling out this form, follow instructions on Form 402-C (a) Rev. 1948.
This form when filled out should be returned to W. C. Barnes, engineer of tests, Association of American Railroads, 59 E. Van Buren St., Chicago, 5, Ill.
*See Instruction No. 3, Form 402-C (a).
**EBF's not included in "All Types Total."

4. TO PROVIDE DATA FOR SPECIAL STATISTICS COVERING TRANSVERSE FISSURE FAILURES ONLY IN CC RAIL, EACH ROAD IS REQUESTED TO FURNISH ONE COPY OF FOREMAN'S REPORT OF EACH SUCH FAILURE IN CC RAIL WHICH IS THOUGHT TO BE DUE TO A TRANSVERSE FISSURE. THIS REPORT SHOULD BE SENT TO THE ENGINEER OF TESTS AS SOON AFTER THE DATE OF THE FAILURE AS POSSIBLE AND THE BROKEN RAIL BE HELD AVAILABLE FOR LABORATORY INVESTIGATION BY THE STAFF OF THE RAILS INVESTIGATION AT THE UNIVERSITY OF ILLINOIS.
5. It should be noted that compound fissures and detail fractures from engine burns, shells, etc. have heretofore been reported unsegregated. The 1948 revision of Form 402–C calls for combined listing of compound fissures and detail fractures and separate listing of engine burn fractures which are not to be included in the "All Types" Total column.
6. Under heading "V.S.H." list vertical split head and under "H.S.H." list horizontal split head failures only.
7. Under "Other Head" list piped rails and crushed heads.
8. Under "Broken" list square or angular breaks in which none of the defects are apparent for which other columns are provided excluding worn out and damaged rails as specified in Instruction No. 1.
9. Fill in the information for rollings in which there were no failures as well as those in which there were failures.
10. Express the gross tonnage of rails and the mile years in whole numbers, the mileage in whole numbers and tenths.
11. This report is now restricted to CONTROL COOLED rail and it is important that the kind of steel be correctly reported. Identify Control Cooled Plain Open-Hearth rail by "OH–CC," Control Cooled Intermediate Manganese rail by "IM–CC" or "MM–CC," substituting an "H" for the final "C" if end hardened.
12. It is important that the report indicate clearly the mill at which the rails were rolled. A list of mills which have rolled rails during recent years is given here together with the corresponding designations which should be entered under "Mill."

Name of Company	*Name of Mill*	*Location*	*Designation*
Algoma Steel Co.	Algoma	S. S. Marie, Ont., Can.	Alg.
Bethlehem Steel Co.	Lackawanna	Lackawanna, N. Y.	Lack.
Bethlehem Steel Co.	Maryland	Sparrows Point, Md.	Md.
Bethlehem Steel Co.	Steelton	Steelton, Pa.	Stltn.
Carnegie–Illinois Steel Co.	Edgar Thompson	Braddock, Pa.	Carn.
Carnegie–Illinois Steel Co.	Gary	Gary, Ind.	Gary
Colorado Fuel & Iron Co.	Minnequa	Pueblo, Colo.	Colo.
Dominion Iron & Steel Co.	Dominion	Sydney, Nova Scotia	Dom.
Inland Steel Co.	Inland	Indiana Harbor, Ind.	Inld.
Tennessee Coal, Iron & R. R. Co.	Ensley	Ensley, Ala.	Tenn.

13. In the first three columns which call for two entries for each item, enter "Mill," "Year Rolled" and "Section" on the first line (opposite "This Year") and "Kind of Steel," "Year Laid" and "lb. per yd." on second line (opposite "total.")
14. To convert tons into track miles, the number of tons may be divided by the figures given below, which show the tons (2240 lb.) of rail per mile of single track for different weights per yard of rail.

80 lb. RA–A	125.71 tons	115 lb. RE	180.24 tons
90 lb. RA–A	141.43 "	127 lb. NYC	200.04 "
100 lb. RA–A	157.77 "	129 lb. TR	203.34 "
100 lb. RA–B	157.93 "	130 lb. RE	203.65 "
100 lb. RE	159.50 "	131 lb. RE	205.54 "
105 lb. NYC	165.00 "	132 lb. RE	207.59 "
110 lb. RE	172.86 "	133 lb. RE	209.63 "
112 lb. TR	176.47 "	136 lb. LV	214.03 "
112 lb. RE	176.79 "	152 lb. PRR	238.23 "

15. Each line for the different year's rollings should be completely filled in without the use of ditto marks.
16. For reporting "Mile Years," i.e. service of rails:
Rail laid in any month of the report year is considered to have zero years age, hence zero mile years of service that year. Rail laid in any month of the preceding year is considered to have one year of service and similarly rail laid in preceding years would have ages of 2, 3, etc. years. Correspondingly, rail removed from track in any month of the report year is considerer to have one full year of service that year and would disappear from the road's reports for subsequent years.

For Example:

Assume 30 miles of rail rolled in calendar year 1937 of which
10 miles are laid in 1937
20 miles are laid in 1938
5 miles of the rail laid in 1937 removed from track in 1940
All the remainder of the above rail remained in track.

The reports for succeeding years would show service of these rails as follows:

Date of Report	*Year Rolled*	*Year Laid*	*Equiv. Track Mi.*	*Mi. Yrs.*	*Period*
Dec. 31, 1937	1937	1937	10	0	This Yr.
				0	Total to Date
Dec. 31, 1938	1937	1937	10	10	This Yr.
				10	Total to Date
	1937	1938	20	0	This Yr.
				0	Total to Date
Dec. 31, 1939	1937	1937	10	10	This Yr.
				20	Total to Date
	1937	1938	20	20	This Yr.
				20	Total to Date
Dec. 31, 1940	1937	1937	10	10	This Yr.
				30	Total to Date
	1937	1938	20	20	This Yr.
				40	Total to Date
Dec. 31, 1941	1937	1937	10	5	This Yr.
				35	Total to Date
	1937	1938	20	20	This Yr.
				60	Total to Date

FORM 402–L

1. This form, as heretofore, calls for report of progressive type failures which occurred *in the report year* in rail of ALL AGES MADE BY ALL PROCESSES and differs from the 1946 revision primarily in the segregation of Engine Burn Fractures. Failed rails are to be reported, not individual failures. As the detected failures in other than control cooled rail are not universally broken for inspection, the information requested for detected failures differs from that for service failures.

In case of doubt as to the interpretation of Form 402-C and Form 402-L or of any of these instructions, write to the engineer of tests, Rail Investigations Committee, Association of American Railroads, 59 East Van Buren Street, Chicago 5, Ill.

Form 402-L Rev. 1948

Report of Annual Progressive Type Failures in Rail of all Ages, Made by ALL Processes

Date ..... 19....

Engineer of Tests

Dear Sir:

The ..... Railroad reports the following for the year January 1, 19.... to December 31, 19..

Service Failures

Transverse Fissures .....

All *other* Transverse Defects including Compound Fissures and Detail Fractures .....

Engine Burn Fractures .....

Detected Failures

Transverse Fissures verified by breaking .....

All Transverse Defects including Unverified Transverse Fissures, Compound Fissures and Detail Fractures .....

Engine Burn Fractures .....

This report covers our entire system .....

This report covers only the following roads .....

Equivalent single main track miles in report territory .....

Yours very truly,

Name .....

Official Title .....

Address .....

Report on Assignment 3

Rail Failure Statistics

W. C. Barnes (chairman, subcommittee), C. B. Bronson, L. T. Nuckols.

These statistics present the rail failures reported to December 31, 1946, and are submitted as information.

In this report the term transverse fissure includes fissures which originated in shatter cracks and other subsurface defects, such as hot torn steel, inclusions and welded up engine burns.

Table 1, prepared from reports on form 402-L and from 402-E for years prior to 1945, lists the transverse fissured rails which occurred each year from 1937 to 1946, incl., service and detected separately, in rails of all ages, made by all processes, segregated as to roads. In this table a zero indicates that the road reported no transverse fissure failures, while a dash indicates no report received for that year. Because of the lack of information as to the track miles of rail of all ages reported on by each road, this table should be used for comparison of failures on individual roads from year to year rather than for comparison of failures as between different roads.

In 1946, 4238 service and 25,831 detected transverse fissure failures were reported compared with 5707 service and 30,813 detected failures reported in 1945. Service failures in 1946 were by far the lowest that have been reported in the last 21 years (see Fig. 1). This result can be attributed to continued intensive detector car testing and to the increasing perecntage of control cooled rail in track. As Table 1 includes transverse fissure failures in rails of all ages, the percentage that control cooled rail bears to total rail in track is unknown but such percentage increased from 14 percent for 1935 rollings to 100 percent for 1945 rollings (see Fig. 3), and it may be inferred that control cooled rail replaced open-hearth rail predominantly in the heavier traffic tracks where transverse fissures were most likely to occur.

Fig. 1 charts the data from Table 1 of this report and from reports of previous years.

Table 2 lists the tons and track-miles of control cooled and all other process rails rolled in the years 1936–1945, incl., which are included in these statistics.

Table 3 shows the combined service and detected failure rates of all types of failures accumulated in one to ten years' service, of rails rolled in 1933 to 1945. This table includes failures from all roads whose reports are complete. Attention is called to the marked decrease in failures starting with 1937 rollings when the purchases of control cooled rail first exceeded those of open-hearth rail (see Fig. 3).

Fig. 2 is a continuation of the chart previously presented showing the rates of failure of all types in various rollings accumulated in five years' service.

Fig. 3, previously referred to, charts the rapid introduction of control cooled rail and the declining use of other process rail. The 1945 rollings reported were 100 percent control cooled.

Table 4 shows separately the track miles and the 1946 failures of all types in open-hearth control cooled rail, Brunorized rail, and intermediate manganese control cooled rail, by roads and by mills, the total track miles of open-hearth control cooled rail being 51,209, of Brunorized 766, and of intermediate manganese control cooled rail 61. The mileage of intermediate manganese control cooled rail is less than that reported in Table 4 of last year's report which included rail rolled in 1935. The mileage of Brunorized rail is also slightly less than reported last year due to a correction since received in the report from one road.

TABLE 1.—TRANSVERSE FISSURED RAILS BY RAILROAD AND BY YEAR FAILED—ALL ROLLINGS, OF ALL PROCESSES

	SERVICE FAILURES											DETECTED FAILURES										
Year Failed	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	Total	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	Total
AT&SF	92	43	85	111	140	341	455	307	141	157	1872	247	194	326	377	275	566	831	647	538	580	4581
ACL	102	66	67	114	121	250	218	267	50	51	1306	180	251	141	118	288	809	1220	870	1302	924	6103
Ban. & Aroos	0	0	0	0	0	3	3	4	3	1	14	0	0	0	0	0	0	0	0	0	49	49
B&OCT								2	0	0	2								0	0	0	0
B&LE								10	6	9	25								0	0	0	0
B&M	14	28	25	11	20	20	42	64	17	11	252	207	45	706	927	785	661	884	276	695	315	5501
B&O	431	382	282	341	459	588	425	367	332	205	3812	652	807	431	609	797	1421	1269	780	844	978	8588
CP	138	114	164	225	501	425	381	238	274	214	2674	1501	1239	1780	2011	3813	5201	5964	5064	4957	3105	34635
C. of Ga	55	59	70	77	109	62	77	61	58	31	659	119	110	91	130	248	223	407	179	157	184	1848
C. of N.J	112	90	69	87	81	77	77	71	48	45	757	0	0	0	0	0	0	0	0	0	3	3
C&EI	22	23	15	15	23	31	48	51	62	57	347	65	77	89	96	120	138	271	352	304	338	1850
C&O	310	187	145	93	100	123	107	71	57	68	1261	891	923	786	533	539	417	540	393	458	465	5945
C&NW	41	38	47	62	78	162	168	160	135	137	1028	317	294	465	631	820	1463	1495	1578	1641	1176	9880
CB&Q	167	134	151	161	199	272	323	287	244	141	2079	413	602	662	668	747	774	1733	1245	1342	1408	9594
CI&L								12	16	8	36								19	21	57	97
CMStP&P	53	46	45	73	77	119	136	136	132	79	896	357	288	285	311	340	684	468	1062	1083	1069	5947
CRI&P	121	98	74	91	115	158	247	183	168	123	1378	344	366	336	269	136	390	605	645	643	527	4261
C&S								26	21	3	50								28	47	82	157
D&H								67	31	14	112								192	196	114	502
DL&W	75	72	72	56	85	96	23	27	29	36	571	454	461	400	140	0	1089	369	333	300	303	3849
D&RGW								203	212	159	574								114	254	190	558
Erie	229	123	133	110	129	210	207	177	99	98	1515	166	264	350	238	599	405	1133	971	549	666	5341
Fla. E.C								152	92	67	311								367	119	164	650
GN	276	215	246	232	224	225	261	243	247	266	2435	69	92	142	171	150	258	366	430	535	516	2729
GM&O	76	55	83	62	85	57	48	29	54		549	0	0	0	0	0	28	298	306	60		692
GTW								43	43	13	99								112	112	83	307
IC (Sys.)	540	515	520	474	556	699	534	311	197	64	4410	447	557	596	727	471	1483	2000	1925	1907	1314	11427
KCS								14	21	4	39								178	66	94	338
L&HR	5	6	8	11	2	10	1	8	0	0	51	0	0	0	22	0	24	0	24	13	12	95
L&NE	6	1	5	4	1	8	3	5	2	7	42	24	0	0	26	0	27	12	4	15	16	124
LV	28	52	41	30	30	79	41	33	49	22	405	0	0	218	6	150	171	128	189	156	67	1085
L&N	229	178	178	130	139	202	217	160	159	116	1708	577	530	408	530	561	925	800	747	684	648	6410
Me. Cen								12	15	14	41								21	63	50	134
MStP&SSM								13	49	23	85								39	24	96	159
MKT	30	35	80	66	110	81	131	92	57	28	710	167	169	61	132	4	455	249	515	214	141	2107
Mo. Pac. R.R							228				228							1328				1328
Mo. Pac. Lines							68	25	24	31	148							502	728	399	462	2091
NC&StL	36	19	30	35	48	39	57	58	43	32	397	42	70	42	115	110	126	218	172	184	68	1147
NYC (Sys.)*	367	389	433	357	462	617	652	406	344	225	4252	322	430	562	352	428	623	844	559	1119	750	5989
NYC&StL							192	86	47	29	354							392	318	199	215	1124
NYC Transit								3	3	6	12								0	0	0	0
NYNH&H	48	39	31	28	30	34	24	21	14	3	272	101	92	110	58	98	121	268	136	74	86	1144
NYO&W	37	55	33	20	20	32	16	62	6	1	282	0	0	0	0	0	0	0	53	0	56	109

TABLE 1.—*Continued*

Year Failed	SERVICE FAILURES											DETECTED FAILURES										
	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	Total	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	Total
N&W	36	22	21	10	7	9	2	3	1	5	116	84	45	44	53	63	49	34	40	40	58	510
NP	259	213	185	147	217	241	317	310	288	289	2466	292	246	310	227	326	470	589	440	471	702	4073
PRR**	672	513	442	323	425	440	517	365	415	290	4402	757	857	920	1158	1048	858	799	1026	909	646	8978
PM	8	4	2	2	0	9	15	4	1	1	46	137	34	27	20	14	111	124	87	27	23	604
P&LE	----	----	----	----	----	----	----	4	0	3	7	----	----	----	----	----	----	----	4	6	1	11
Reading	186	164	191	148	283	267	172	173	70	49	1703	0	0	0	0	0	0	0	367	735	287	1389
RF&P	4	3	2	5	16	27	28	31	27	20	163	53	52	61	37	186	168	238	228	207	176	1406
Rutland	1	1	2	2	2	1	1	3	1	2	16	0	0	0	0	0	8	0	0	0	0	8
Seaboard	----	----	----	----	----	----	----	49	23	24	96	----	----	----	----	----	----	----	197	159	299	655
S.P. (Pac. Lines)	481	394	590	347	356	452	426	445	267	209	3967	629	637	477	709	1424	1610	2002	1536	1377	1362	11763
Sou. (Sys.)	504	256	226	258	256	337	311	278	277	246	2949	0	1263	1061	1101	2151	2454	3541	2360	1955	1835	17721
StLSF	----	----	----	----	----	----	----	111	142	102	355	----	----	----	----	----	----	----	573	655	415	1643
T&NO	----	----	----	----	----	----	----	239	186	123	548	----	----	----	----	----	----	----	795	924	837	2556
Tex. & Pac	----	----	----	----	98	93	160	128	124	72	675	----	----	----	----	----	760	758	839	869	582	524	4332
UP (Sys.)	1443	923	1033	481	395	447	389	226	241	176	5754	1996	2032	2525	3022	4226	4479	3045	1587	1356	1148	25416
Virginian	36	34	39	30	27	16	12	11	13	10	228	0	0	0	126	90	173	114	114	0	0	617
W. Md.	70	133	50	53	43	48	35	26	27	14	499	86	0	72	82	148	228	152	184	133	144	1229
W&LE	----	----	----	----	----	----	----	3	3	5	11	----	----	----	----	----	----	----	0	3	3	6
All Roads	7340	5722	5915	4882	6069	7407	7795	6976	5707	4238	62051	11696	13027	14484	15732	21915	29848	36071	31978	30813	25831	231395

----No report received.
*Including IHB failures.
**Including L.I.R.R. & P-R.S.L.

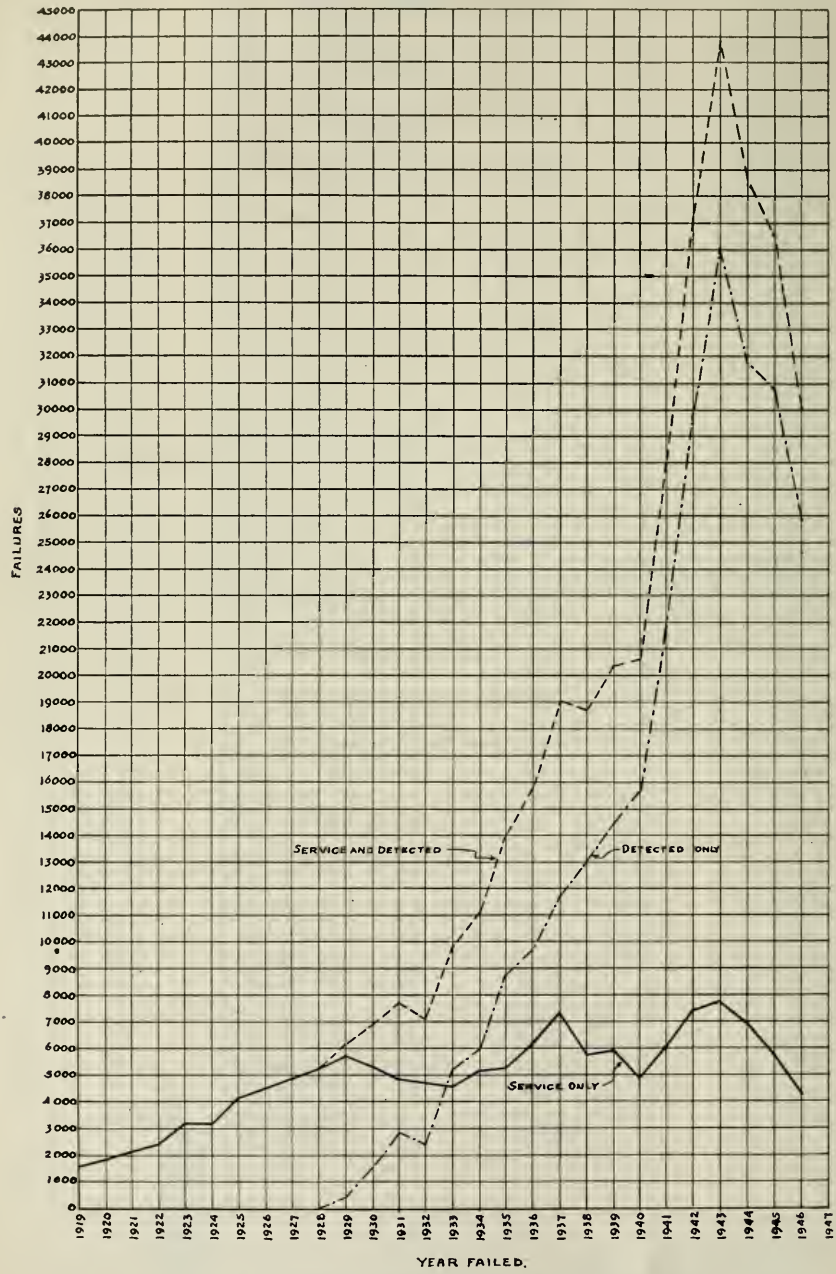


Fig. 1.—Total Transverse Fissured Rails Reported Each Year. Rails Made by All Processes Included. 1930 Includes 11 Months Only.

TABLE 2.—TONS AND TRACK-MILES OF EACH YEAR'S ROLLINGS 1936–1945, INCL., INCLUDED IN THESE STATISTICS

All Roads and All Processes from All Mills

Year Rolled	*OH Control Cooled Only*		*Brunorized and "Other" Process*		*Total*	
	Tons	*Track-Miles*	*Tons*	*Track-Miles*	*Tons*	*Track-Miles*
1936	354,613	1926.71	378,963	2099.59	733,576	4026.30
1937	697,183	3860.20	283,063	1525.64	980,246	5385.84
1938	396,178	2220.26	60,973	362.14	457,151	2582.40
1939	783,694	4189.46	56,892	327.12	840,586	4516.58
1940	874,890	4750.89	52,846	316.44	927,736	5067.33
1941	1,042,322	5587.33	40,414	232.09	1,082,736	5819.42
1942	1,088,224	5877.64	14,129	95.61	1,102,353	5973.25
1943	1,265,344	6850.82	12,143	77.24	1,277,487	6928.06
1944	1,549,843	8360.79	7,845	54.12	1,557,688	8414.91
1945	1,511,352	7585.28	0	0	1,511,352	7585.28
Total	9,563,643	51,209.38	907,268	5,089.99	10,470,911	56,299.37

TABLE 3.—SERVICE AND DETECTED FAILURES OF ALL TYPES ACCUMULATED FROM DATE ROLLED TO DECEMBER 31, 1946, PER 100 AVERAGE TRACK MILES, IN ALL ROLLINGS BY ALL PROCESSES FROM ALL MILLS

Year Rolled	Years Service									
	1	2	3	4	5	6	7	8	9	10
1933	6.2	11.7	25.6	52.4	73.5	91.6	122.9	174.9	246.3	332.0
1934	4.6	13.6	19.3	25.9	35.8	53.1	80.1	116.7	175.9	233.1
1935	4.2	9.6	16.3	32.3	51.0	85.8	129.0	213.5	326.9	445.1
1936	4.2	7.3	18.1	30.6	50.7	90.7	144.7	228.7	333.4	453.2
1937	3.3	5.8	11.3	15.9	23.9	39.3	67.8	100.1	140.4	
1938	2.2	5.2	10.4	20.7	32.6	48.7	63.9	80.9		
1939	2.6	5.0	9.9	20.8	36.8	58.3	90.0			
1940	1.3	3.1	8.7	18.3	37.2	73.0				
1941	1.5	4.0	9.0	23.4	44.8					
1942	2.2	6.1	11.7	25.7						
1943	3.6	8.9	17.3							
1944	3.6	7.3								
1945	1.4									

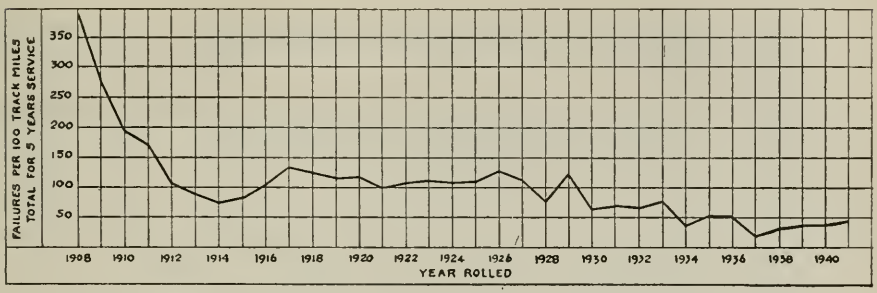


Fig. 2.—Service and Detected Rail Failures in the United States and Canada.

Table 5 presents the accumulated failures in rollings of 1936–1945, incl., by type of failure and by mill, open-hearth control cooled and intermediate manganese control cooled shown separately. The total mileages shown differ slightly from those in Tables 2 and 4 due to necessary elimination from Table 5 of the incomplete report of one road.

Table 6 lists the transverse fissure failures in control cooled rail accumulated from the year rolled to September 1, 1947, all of which have been verified by Professor Cramer at the University of Illinois. This table segregates the failures by roads, by mills and by the year rolled. The origins of the failures are also shown. It will be noted that a total of only six transverse fissures originated from shatter cracks, which the control cooling process was intended to prevent, and these six were in rails rolled at one mill in 1936 to 1938 and were caused by the use of unsuitable cooling box covers. Shortly after 1938 these covers were insulated to overcome this difficulty.

In former years Table 6 included data on brunorized rail but this has been omitted in this year's report because of the fact that all of the transverse fissure failures in such rail have occurred in rail rolled before the process was revised in April 1938 and failures in Brunorized rail made by the old process are no longer examined by the University of Illinois. No transverse fissure failures have occurred in the Brunorized rail made by the new process, the rolling of which, however, was discontinued in November 1941.

Table 7 is a comparison of rail failures of all types accumulated from date rolled to December 31, 1946, per 100 track-miles, separately for control cooled, Brunorized and other process rails, rolled 1936–1945, incl. This table includes reports from the same roads that were used in Tables 3 and 5.

Fig. 4 charts the data from Table 7 and compares the failure rates from the date rolled to December 31, 1946, of open-hearth control cooled and other process rails, from rollings 1936–1945, incl., that is, ten years' service of the 1936 rollings to one year's service of the 1945 rollings. All types of failure are included. The smooth curve of the control cooled rail failure rates contrasts with the very irregular curve of the open-hearth failure rates.

Fig. 5 is a mill rating chart showing the failure rates per 100 track mile years of open-hearth control cooled rail only, all types, by mills, in rollings 1938 to 1945, incl., from the date rolled to December 31, 1946, unweighted for traffic. Insufficient tonnage has been reported for the inclusion of Dominion rollings. Many web failures within the limits of the joint bars, reported by one road, materially increased the failure rates of Carnegie-E.T. 1939 and 1940 rollings and of Inland 1940 and 1942 rollings (see Table 5).

Table 4.—Control Cooled and Brunorized Contract Rail

Track-Miles and Failures, All Types, in Rollings 1936 to 1945, Incl.

Road	Brunorized		OH Control Cooled											
	Trk. Mls.	1946	Track Miles											1946
	Gary	Failures	Alg.	Carn.	Colo.	Dom.	Gary	Inld.	Lacka.	Md.	Stltn.	Tenn.	Total	Failures
AT&SF					2858		692	121			74		3745	313
ACL				93							204	387	684	11
B&O				569			433	14	102		236		1354	109
B&Aroos.											42		42	0
B&OCT							10	13					23	0
B&LE				133									133	3
Bos. & Alb.									167				167	5
B&M				139					171		160		470	14
CP			3077			182			96				3355	196
C of Ga.												309	309	16
C of NJ											196		196	6
C&O				43			928	512			167		1650	293
C&EI							210	36					246	9
C&NW	111	82					671	207					878	42
CB&Q	136	13			744		680	225					1649	24
CCC&StL	16	0					681	8	45				734	13
CI&L							59						59	0
CMStP&P	255	19					822	322					1144	33
CRI&P					404		1060	319					1783	30
C&S					13								13	0
D&H											386		386	96
DL&W				70					308		12		390	14
D&RGW					465								465	60
Erie				668			287	56	140				1151	35
Fla. E.C.				11								263	274	4
GTW							233	56					289	3
GN	126	19					519	153	238				910	46
IC	32	11					1020	439				368	1827	63
IHB								16					16	0
KCS	27	15					322	63			10		395	6
L&HR											22		22	0
L&NE				10							21		31	0
LV									216				216	8
L&N							198					1517	1715	147
Me. Cent.									59				59	0
Mich. Cen.	15	1	302				197						499	17
MStP&SSM							38	6	10				54	4
MKT					54		372	56					482	12
MPRR				15	942		408	252				146	1763	109
MP Lines					244							120	364	7
NC&StL							4					378	382	82
NYC—East				55					891				946	106

TABLE 4.—*Continued*

Road	Brunorized		OH Control Cooled											
	Trk. Mls.	1946	Track Miles											1946
	Gary	Failures	Alg.	Carn.	Colo	Dom.	Gary	Inld.	Lacka.	Md.	Stltn.	Tenn.	Total	Failures
NYC—West	29	3					430	99	179				708	374
NYC&StL				26			391	101	89				607	55
NYNH&H				340							280		620	33
N&W				803							267		1070	105
NP					267		825	28	372				1492	58
PRR				1117			780	153	40		1181		3271	3761
P&E								4					4	0
PM			95	167				96	40				398	3
P&LE				128									128	4
Reading											236		236	0
RF&P											100		100	56
Rutland									8				8	7
Seaboard											539	577	1116	40
StLSF							10	10				703	723	33
SP					2011						467	685	3163	641
Sou. Ry.							115				494	1222	1831	94
T&NO					489						151		640	8
T&P					335							292	627	39
UP	19	0			1505		880	222					2607	595
Va.				106					5		187		298	5
W. Md.				29							40		69	1
W&LE				223									223	15
Total	766	163	3474	4745	10331	182	13275	3587	3176		5472	6967	51209	7863
			IM Control Cooled											
D&H											45		45	8
D&RGW					16								16	186
Total					16						45		61	194

Fig. 3.—Chart Showing Rapid Adoption of Open-Hearth Control Cooled Rail.

TABLE 5.—ACCUMULATED FAILURES AND FAILURES PER 100 TRACK-MILES, IN ROLLING 1936 TO 1945, INCL., FROM DATE ROLLED TO DECEMBER 31, 1946, SERVICE AND DETECTED, BY MILL AND TYPE OF FAILURE

OH Control Cooled Rail Only

Mill	Accumulated Failures to December 31, 1946									Avg. Track Miles	Track Mile Years	Failures per 100 Track Mile Years
	Transv. Fiss.	Comp. Fiss. Det. Frac. from Eng. Burns, Shells, etc.	VSH and HSH	Other Head	Broken	Web		Base	All Types			
						In Jt.	Other					
Algoma	1	2	230	1	40	137	28	203	642	3,474.01	13,598	4.72
Carnegie (ET)	2	405	160	71	244	3461	1260	10	5613	4,801.85	20,275	27.68
Colorado	0	701	814	283	140	77	408	25	2448	10,086.47	41,406	5.91
Dominion	0	0	2	0	0	7	1	0	10	181.73	1,425	0.70
Gary	7	685	283	157	257	744	332	88	2553	13,203.34	52,384	4.87
Inland	14	553	122	54	136	413	238	38	1568	3,587.19	18,463	8.49
Lackawanna	1	180	53	49	121	415	56	123	998	3,176.45	14,283	6.99
Maryland												
Steelton	44	725	221	208	455	105	358	6	2122	5,472.13	22,046	9.63
Tennessee	0	85	857	351	489	327	584	109	2802	6,847.41	31,526	8.89
All Mills	69	3336	2742	1174	1882	5686	3265	602	18756	50,830.58	215,406	8.71
Failures per 100 Tr. Mi. Years	0.03	1.55	1.27	0.55	0.87	2.64	1.52	0.28	8.71			

IM Control Cooled Rail Only

Colorado	0	359	19	4	4	6	0	0	392	15.81	95	412.63
Steelton	0	1	1	0	1	22	0	0	25	45.05	398	6.28
All Mills	0	360	20	4	5	28	0	0	417	60.86	493	84.58
Failures per 100 Tr. Mi. Years	0	73.02	4.06	0.81	1.01	5.68	0	0	84.58			

Note: Causes of transverse fissure failures are indicated on Table 6

Table 6.—Accumulated Transverse Fissure Failures by Road, Mill and Year Rolled to September 1, 1947, OH Control Cooled Rail

(CC Failures Verified by Laboratory Investigation)

OH Control Cooled Only

Roads	*Mills*	*1935*	*1936*	*1937*	*1938*	*1939*	*1940*	*1941*	*1942*	*1943*	*1944*	*1945*	*Total*
PM	Algoma						1						1
NY NH & H	Carnegie (ET)			1(d)									1
N& W	Carnegie (ET)					1							1
C&O	Gary		2(b)				1(b)						3
C&NW	Gary		1(a)	1(a)									2
CB&Q	Gary		3(a)										3
NYC	Gary				1(a)								1
C&O	Inland	1	4(c)	2	1			4			1	1	14
UP	Inland					3	2						5
LV	Lackawanna								1	1			2
B&O	Steelton								1	1			2
B&M	Steelton						2						2
C&O	Steelton	1		1	3			1					6
D&H	Steelton				1	1	1			1			4
N&W	Steelton					1	1		2				4
NY NH & H	Steelton			3			1		1	1			6
PRR	Steelton		2										2
RF&P	Steelton			1			1						2
SAL	Steelton							2		1			3
SoRy	Steelton							1		1			2
SP	Steelton		16	2	5	1							24
	TOTAL	2	28	11	11	7	10	8	5	6	1	1	90
	Algoma						1						1
	Carnegie (ET)			1		1							2
	Colorado	*											0
	Dominion												0
	Gary		6	1	1		1						9
	Inland	1	4	2	1	3	2	4			1	1	19
	Lackawanna								1	1			2
	Maryland	*	*	*	*	*	*	*	*	*	*	*	0
	Steelton	1	18	7	9	3	6	4	4	5			57
All Roads	All Mills	2	28	11	11	7	10	8	5	6	1	1	90

*No CC rail rolled.

Note: (a) T.F. from shatter cracks due to use of improper cooling box covers. (b) T.F. from welded engine burns. (c) One T.F. from welded engine burns. (d) T.F. from silicate inclusion. Summary—6 T.F.s from shatter cracks, 4 T.F.s from welded engine burns, 1 T.F. from inclusions, 79 T.F.s from hot torn steel.

TABLE 7.—COMPARISON OF RAIL FAILURES OF ALL TYPES ACCUMULATED FROM DATE ROLLED TO DECEMBER 31, 1946, PER 100 AVERAGE TRACK MILES OF CONTROL COOLED, BRUNORIZED AND "OTHER" PROCESS RAILS ROLLED IN 1936 TO 1945, INCL., SERVICE AND DETECTED

Year Rolled	*1945*	*1944*	*1943*	*1942*	*1941*	*1940*	*1939*	*1938*	*1937*	*1936*
Years Service	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Control Cooled Rail (Excl. IM–CC Rail)	1.41	7.24	16.50	24.88	46.31	67.91	70.37	65.23	98.42	123.85
Brunorized*					6.90	8.29	3.76	112.23	196.83	254.34
"Other" Process Rail**		18.35	85.34	71.58	16.13	272.90	550.37	188.62	257.11	756.25
Rail Made by All Processes	1.41	7.32	17.30	25.66	44.81	72.99	90.07	80.94	140.44	453.16

Note: ** "Other" Process Rail includes Bessemer, plain open hearth, medium maganese, control cooled medium maganese, etc. and excludes control cooled OH and Brunorized.

Dates on which rolling of contract rail started

Control Cooled

Dominion—Jan. 1931
Algoma—Dec. 1933
Steelton—Mar. 1935
Inland—Apr. 1935
Lackawanna—May 1935
Carnegie—Oct. 1935
Colorado—Jan. 1936
Tennessee—Feb. 1936
Gary—Apr. 1936

**Brunorized*

Gary—old process—Oct. 1936
revised process—Apr. 27, 1938
rolling discontinued—Nov. 18, 1941

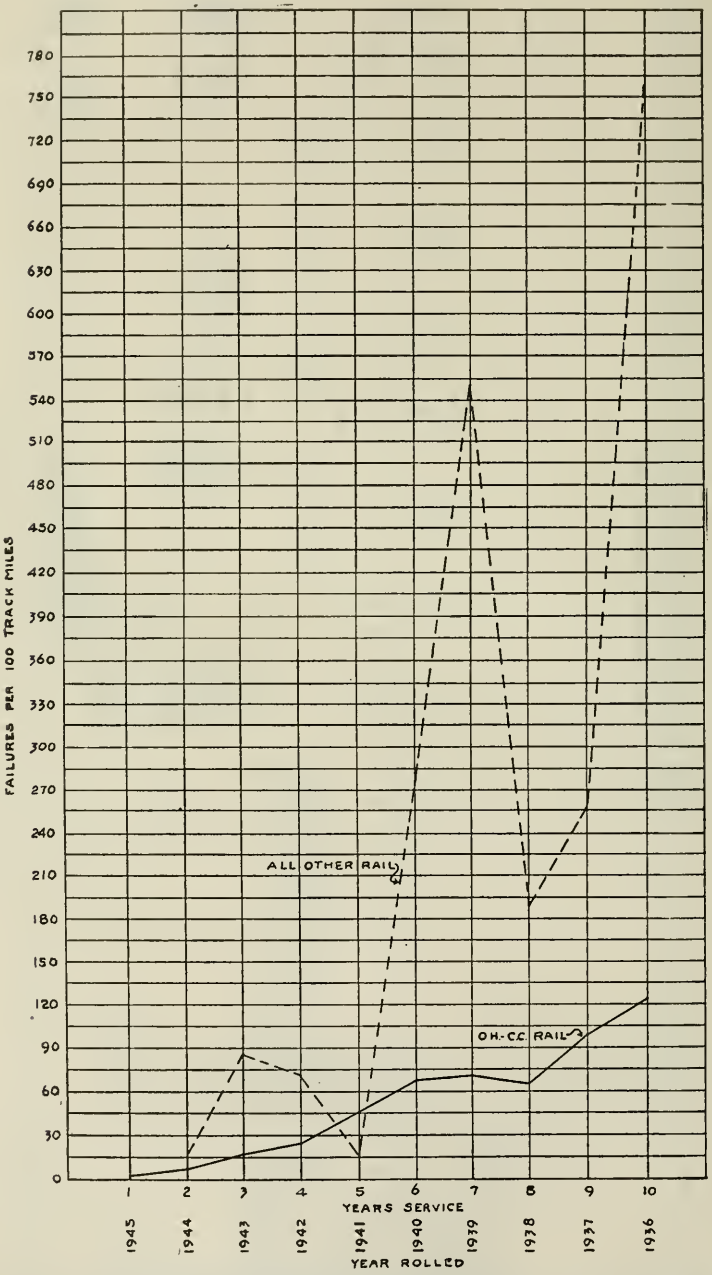


Fig. 4.—Control Cooled and Other Process Rail Failures to December 31, 1946, per 100 Track Miles—Service and Detected—Brunorized Rail Excluded.

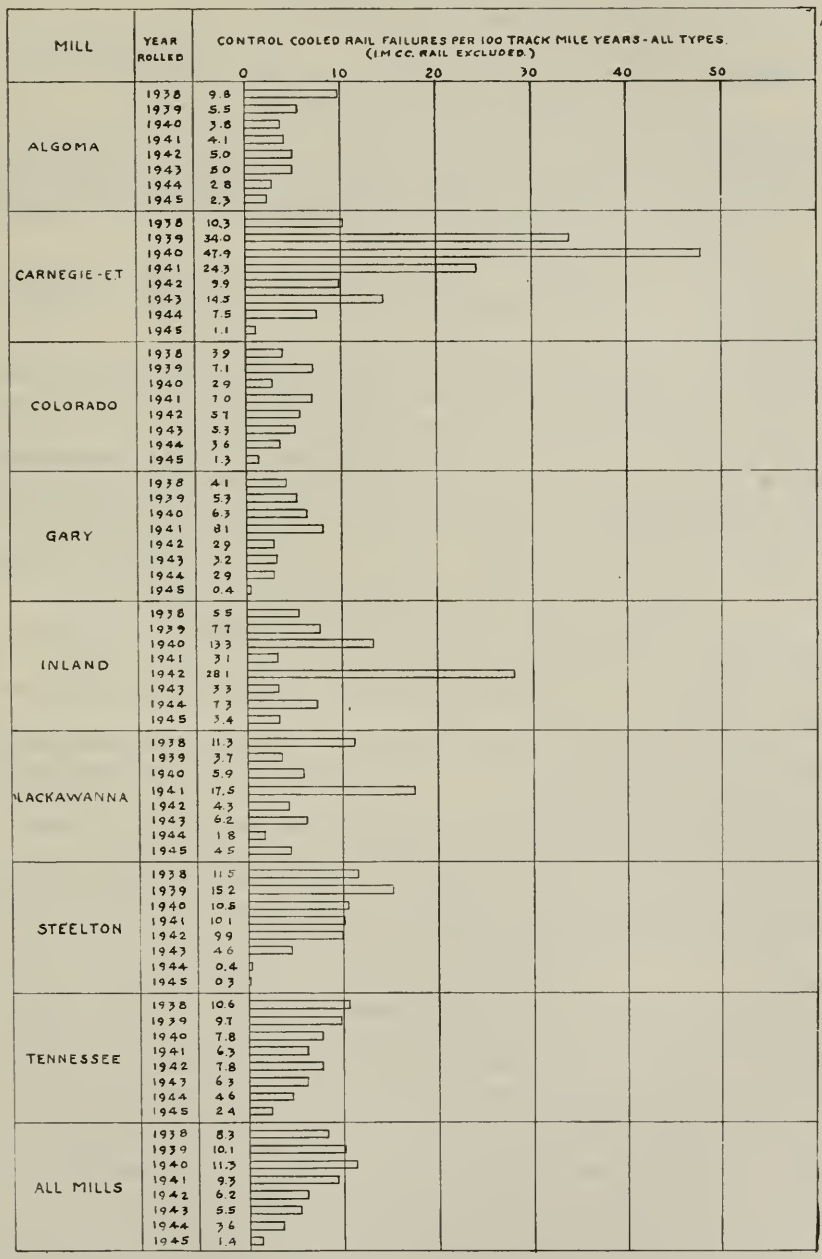


Fig. 5.—Control Cooled Rail Failure Rates to December 31, 1946—All Types—Service and Detected. Not Weighted for Traffic. Failures Due to Design, Traffic and Manufacturing Defects Included.

Report on Assignment 4

Methods of Hardening Rail Ends and Reconditioning Them to Control Rail Battering

R. P. Winton (chairman, subcommittee), H. Austill, W. C. Barnes, C. H. Blackman, C. B. Bronson, C. M. Chumley, H. R. Clarke, C. J. Code, E. M. Hastings, F. S. Hewes, H. S. Loeffler, G. M. Magee, E. E. Mayo, Ray McBrian, C. E. Morgan, L. T. Nuckols, E. E. Oviatt, J. G. Roney, J. C. Ryan, R. T. Scholes, I. H. Schram, F. S. Schwinn, E. C. Vandenburgh, J. C. Wallace.

This report on measurement of profiles and batter of rail ends is offered as information, with the recommendation that a part thereof be adopted and published in the Manual.

There is a need for an instrument for measuring profiles of rail ends out beyond the limits of the joint bars for studies of batter and low joints.

The 10-in. batter gage shown in Fig. 417 on page 4–53 in the Manual is not entirely satisfactory because the straight edge is too short for many purposes; the straight edge cannot be held firmly on the rail, the slider, which holds the dial indicator, is not held firmly on the straight edge, and the contact point of the indicator can drop down in the gap between the two rail ends.

The proposed profile gage shown in Figs. 1 and 2 has the following desirable features:

1. The straight edge is 48 in. long with the zero in the center and is graduated in both directions.

2. The carriage for the dial indicator is held tight against the top of the straight edge by a spring.

3. There is a ball click fitting into depressions on the bottom of the straight edge, which locates the carriage accurately at the graduations at zero, ½ in. either side of zero, and at 1-in. points thereafter.

4. The dial indicator has a top lift so that the contact point can be lifted when it passes across the gap at the ends of the rail.

5. The indicator has a total travel of ½ in., which will measure considerable batter at low joints. The indicator has a telltale hand which counts the revolutions of the long hand, so there is no possibility of error.

6. The instrument can be quickly attached to the rail and held firmly by Alnico magnets.

The profile measured by this instrument includes the effect of low joints as well as battered rail ends. In order to get the true batter it is necessary to plot the readings and draw a tangent to the unbattered portion of the rail so that the batter at the end of the rail can be scaled from the tangent.

The profile gage shown in Fig. 1 is large and difficult to use and it is necessary to plot the readings of the profile gage before the batter can be scaled. There is a real need for a simple light instrument which will measure true batter quickly. The rail batter gage shown on page 191 in 1929 AREA Manual was fairly satisfactory but it had to be held on the rail and the straight edge was so thin it could be easily bent.

The batter gage shown in Fig. 3 has a hardened and ground straight edge ¾ in. wide which will not tip over when placed on the rail. The sides are milled out to lighten it and furnish a finger hold. The dial indicator is 2 in. in diameter so that it can be easily read without stooping over. The contact point has a travel of 0.200 in.

Each division on the dial for the long hand is 0.001 in. Each division on the dial for the smaller telltale hand is 0.100 in. so there is no possibility for error in the number of revolutions of the long hand.

Difference in height of the two rail ends may cause as bad riding track as battered rail ends. Therefore, three measurements should be made as shown in Fig. 4.

Your committee recommends that the matter appearing under the heading Rail Batter on Manual pages 4–52 to 4–54, incl., be withdrawn and that the following statement on the measurement of profiles and batter of rail ends together with the illustrations be adopted and published in the Manual.

MEASUREMENT OF PROFILES AND BATTER OF RAIL

Instructions for Using Profile Gage

The contact point of the dial indicator has a total travel of ½ in. Each division on the outer scale for the long pointer is 0.001 in. The small telltale hand moves one division for each revolution of the long hand which is 0.100 in. When the instrument is placed on a flat surface, the bottom of the straight edge should be about 1 in. above the surface and the indicator should read 0.300 in.

To Adjust Instrument

1. Adjust stop rods so that the center of the supports for the straight edge is in the center of a new rail.

2. (a) Place instrument on a straight rail.
   (b) Move carriage to the extreme left and note reading of indicator.
   (c) Move carriage to extreme right and note reading of indicator.
   (d) Turn bezel on indicator until pointer is equal distances either side of the zero when the carriage is at the extreme right or left.

To Use Instrument

3. Always lift contact point with top lift when passing over the gap between the ends of the rail.

4. Set carriage for the indicator at zero on the straight edge.

5. Place the instrument on the rail with the stop rods against the field side of the head of the rail and the contact point of the indicator in the center of the gap between the two rail ends.

6. Move carriage to left so that the contact point of the indicator is ⅛ in. from the end of the rail. Read the indicator and the distance on the scale on the straight edge.

7. Move carriage to left to ½-in. mark and read indicator.

8. Move carriage to left to 1-in. mark and read indicator.

9. Move carriage to left to successive inch marks and read indicator. The readings at the odd inches beyond 2 in. may be omitted if desired.

10. Move carriage so the contact point of the indicator is ⅛ in. from the end of the right hand rail and read indicator and the distance on the straight edge.

11. Make readings of the indicator on the right hand rail at ½ in. and successive 1-in. points same as 7, 8, and 9.

12. Measure gap between the two rail ends with a scale or taper gage.

Instructions for Plotting Readings of Profile Gage

1. Use cross section paper having a horizontal scale of 1 in. = 1 in. and an enlarged vertical scale such as 1 in. = 0.050 in.

2. Plot readings of profile gage.

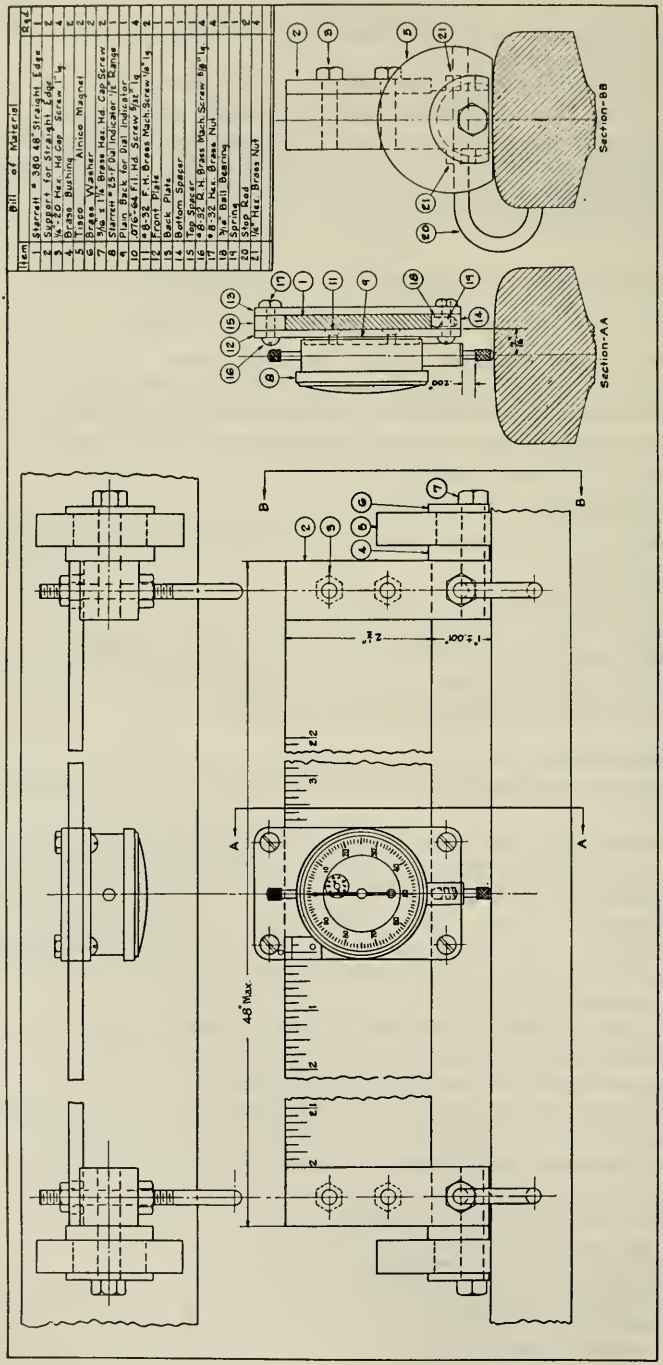

Bill of Material
Item
Qty.
1 Starrett # 360 48" Straight Edge 1
2 Support for Straight Edge 2
3 #4-40 Hex. Hd Cap Screw 1/4" 4
4 Ball Bushing 4
5 Tiseo Alnico Magnet 2
6 Brass Washer 2
7 3/16 x 1/16 Brass Hex. Hd. Cap Screw 2
8 Starrett #15 Dial Indicator 1
9 Plain Back for Dial Indicator 1
10 .076"-64 Fil Hd. Screw 3/32" lg 4
11 #8-32 F.H. Brass Mach. Screw 1/4" lg 2
12 Front Plate 1
13 Back Plate 1
14 Bottom Spacer 1
15 Top Spacer 1
16 #8-32 Q.H. Brass Mach. Screw Dia" lg 4
17 #8-32 Hex. Brass Nut 4
18 Ball Bearing 1
19 Spring 1
20 Stop Rod 2
21 1/4" Hex. Brass Nut 4
Section-BB
Section-AA
48" Max.

Fig. 1.—Profile Gage.

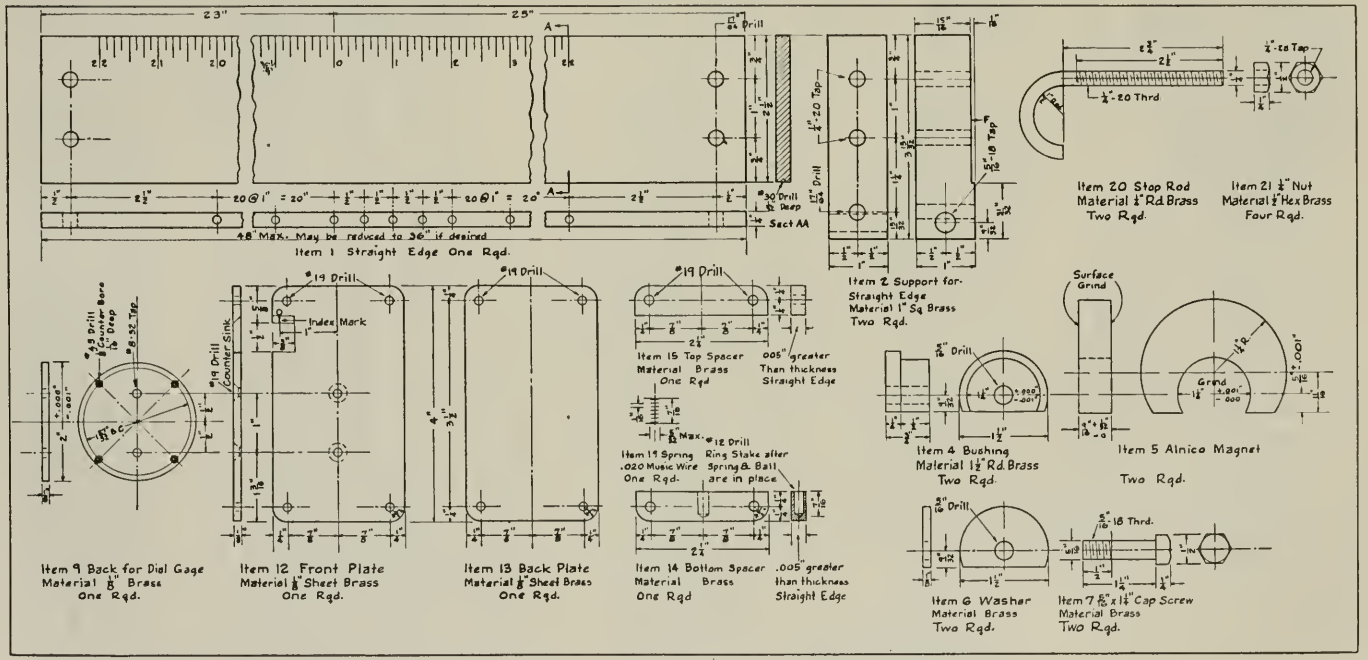

23"
25"
48" Max. May be reduced to 36" if desired
Item 1 Straight Edge One Rqd.
Item 2 Support for Straight Edge Material 1" Sq Brass Two Rqd.
Item 20 Stop Rod Material ¼" Rd Brass Two Rqd.
Item 21 ¼" Nut Material ¼" Hex Brass Four Rqd.
Item 4 Bushing Material 1½" Rd Brass Two Rqd.
Item 5 Alnico Magnet Two Rqd.
Item 6 Washer Material Brass Two Rqd.
Item 7 ⅝" x 1½" Cap Screw Material Brass Two Rqd.
Item 9 Back for Dial Gage Material ⅛" Brass One Rqd.
Item 12 Front Plate Material ⅛" Sheet Brass One Rqd.
Item 13 Back Plate Material ⅛" Sheet Brass One Rqd.
Item 14 Bottom Spacer Material Brass One Rqd
Item 15 Top Spacer Material Brass One Rqd
Item 19 Spring .020 Music Wire One Rqd.
Ring Stake after Spring & Ball are in place
.005" greater than thickness Straight Edge
Index Mark
Surface Grind
Grind

Fig. 2.—Details of Profile Gage.

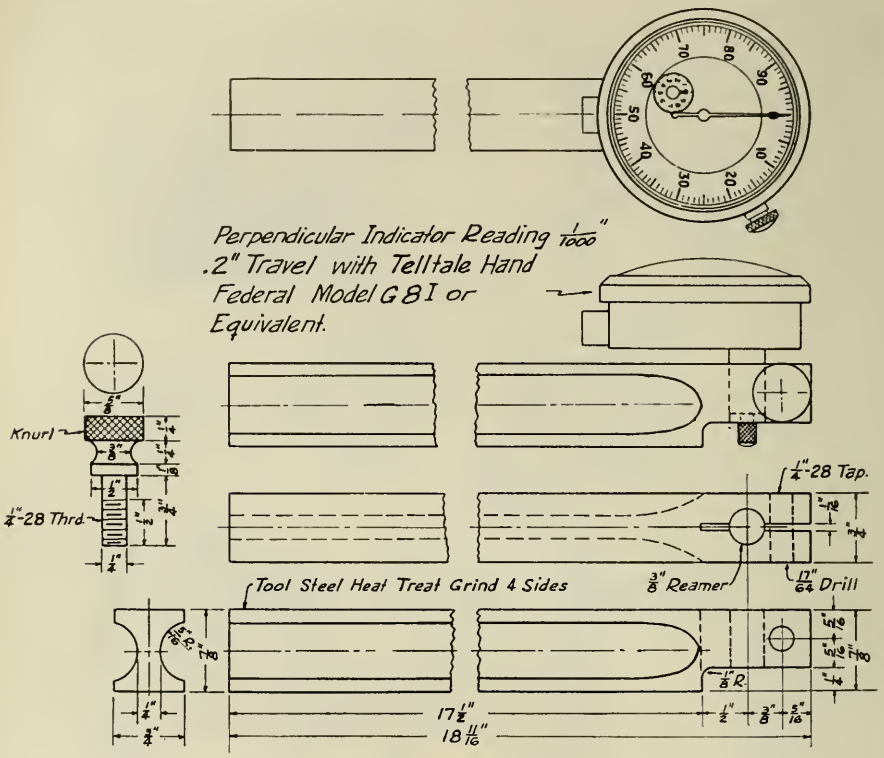


Fig. 3.—Batter Gage.

3. Show gap between ends of two rails.

4. Show direction of traffic.

5. Draw a tangent to the unbattered portion of the leaving rail. Scale from the tangent to the profile at the ⅛-in. point on the leaving rail. This is the batter at the ⅛-in. point on the leaving rail.

6. Draw a tangent to the unbattered portion of the receiving rail. Scale from the tangent to the profile at the ⅛-in. point on the receiving rail. This is the batter at the ⅛-in. point on the receiving rail.

7. Subtract the reading of the indicator at the ⅛-in. point on the leaving rail from the reading at the ⅛-in. point on the receiving rail. This is the difference in height of the ends of the two rails. If this difference is minus, the receiving rail is below the leaving rail.

Instructions for Using Batter Gage

Each graduation on the outer dial is 0.001 in. or 1 mil. One revolution of the long hand is 100 mils. Each graduation on the small dial is one revolution of the long hand or 100 mils. The total travel of the contact point is 200 mils. When the instrument is placed on a flat surface the indicator should read 100 mils.

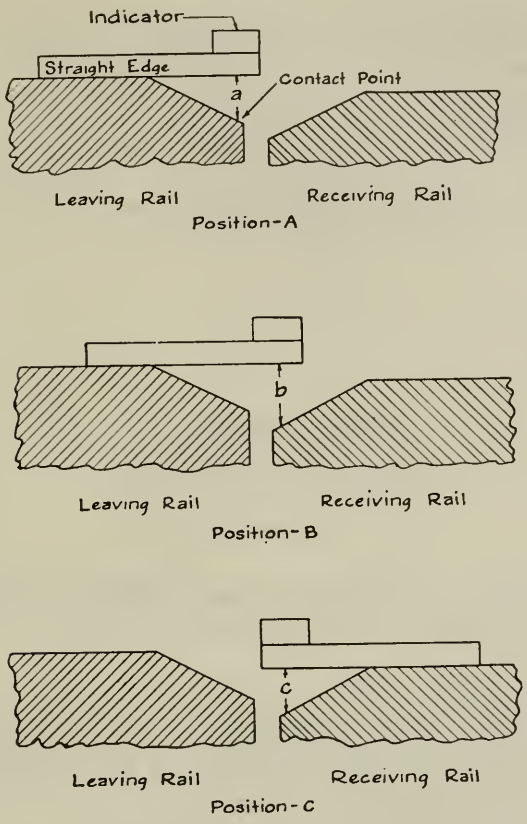


Fig. 4.—Method of Using Batter Gage.

Adjustment

1. Place instrument on a flat surface. (A piece of plate glass can be used if nothing else is available.)

2. Loosen clamp screw and adjust height of indicator so that it reads within 5 mils of 100 mils with the indicator in the position shown in Fig. 3. Tighten clamp screw so that indicator cannot slip but contact spindle moves freely. Do not oil spindle.

3. Loosen bezel clamp screw and turn outer dial until "0" is under the pointer. Tighten bezel clamp.

To Measure Batter

1. Place straight edge on the center line of the leaving rail with the contact point of the indicator ⅜ in. from the end of the leaving rail as shown at position "A" in Fig. 4. Note the reading of the indicator. Call this reading in mils "a." Subtract 100 from reading "a." The difference is the batter on the leaving rail. If the batter is minus, the end of the rail is below the straight edge, but if it is plus, the end of the rail is above the straight edge. Example: $a = 90$; then batter $= 90 - 100 = -10$.

2. Move the straight edge along the leaving rail until the contact point is ⅛ in. from the end of the receiving rail as shown at position "B." Call the reading of the indicator "b." Subtract reading "a" from reading "b" in paragraph 1. The result is the difference in height of the two rail ends. If this result is minus, the receiving rail is lower than the leaving end. Example: a = 91; b = 72; 72 — 91 = — 19. Therefore, the end of the receiving rail is 19 mils below the end of the leaving rail.

3. Turn the instrument around and place it on the receiving rail with the contact point ⅛ in. from the end of the receiving rail as shown in position "C." Note this reading "c." Subtract 100 from reading "c." The difference is the batter on the receiving rail.

Report on Assignment 6

Continuous Welded Rail

Collaborating with Committee 5

I. H. Schram (chairman, subcommittee), S. E. Armstrong, W. C. Barnes, C. H. Blackman, C. B. Bronson, C. J. Code, P. O. Ferris, G. W. Harris, F. R. Layng, H. S. Loeffler, G. M. Magee, R. J. Middleton, C. E. Morgan, L. T. Nuckols, E. E. Oviatt, J. C. Ryan, R. T. Scholes, R. P. Winton.

This is a progress report submitted as information.

The statements that have been prepared this year showing the installations of continuous welded rail have been revised by eliminating those with the older types of welding; i.e., A Gas Fusion, B Gas Fusion and C Thermit, and are presented in summarized form. Data are being gathered on installations of the newer welding processes; they will be submitted next year.

Attention is directed to report of Committee 22—Economics of Railway Labor (Assignments 2 and 4) showing the economies to be realized from the use of continuous welded rail.

CONTINUOUS WELDED RAIL

	Summary of		
	Installations	*Removals*	*Renewals*
C1 Thermite (Type K)	11	3	1 C2 Thermite (Full Fusion)
C2 Thermite (full fusion)	2	0	0
D Electric pressure weld	8	1	0
E Gas pressure weld	9	0	0
Total installations	30		
Total removals		4	
Total renewals			1

SUMMARY OF PROCESSES

Process	In Tunnels			In the Open		
	Installations	Welded Joints	Failures	Installations	Welded Joints	Failures
C1 Thermit (Type K)	4	1734	61	7	2365	25
Removed	3	1228	61			
Remaining	1	506		7	2365	25
C2 Thermit (Full Fusion)	2	1838	6			
Removed						
Remaining	2	1838	6			
D Electric Pressure	1	282	10	7	7277	12
Removed	1	282	10			
Remaining				7	7277	12
E Gas Pressure Weld (Oxweld)	3	520		6	4534	7
Removed						
Remaining	3	520		6	4534	7

STATEMENT OF ADDITIONAL FAILURES

Railroad	Location	Process	Date Installed	Failures Previously Reported	Failures This Report	Total Failures
G. N.	Rexford, Mont.	C1 Thermit	1937	2	1	3
D. & H.	Mechanicsville, N. Y.	C1 Thermit	1939	0	1	1

Report on Assignment 7

Service Tests of Various Types of Joint Bars

Ray McBrian (chairman, subcommittee), J. B. Akers, W. C. Barnes, C. B. Bronson, W. J. Burton, C. M. Chumley, C. J. Code, L. S. Crane, P. O. Ferris, F. S. Hewes, S. R. Hursh, G. M. Magee, E. E. Mayo, C. E. Morgan, R. A. Morrison, L. T. Nuckols, R. E. Patterson, W. C. Perkins, J. C. Ryan, R. T. Scholes, W. D. Simpson, J. G. Wishart.

This is the final report of the service tests of various designs of joint bars for 112 and 131-lb. RE rail which were installed on tangent track on the Atchison, Topeka & Santa Fe Railway and Pennslyvania Railroad in 1937. The tests described in this report were carried out for the Rail Committee by the Engineering Division research staff with funds provided by the Association of American Railroads. Olaf Froseth, assistant track engineer, made the field measurements and reduced the data under the general direction of G. M. Magee, research engineer, and E. E. Cress, assistant research engineer.

Santa Fe Installation

Nine different designs of joint bars for 112-lb. RE rail were installed in the westbound main track of the Santa Fe west of Streator, Ill., in June 1937 at the time of laying new rail. The south rail was end-hardened; the north rail was not. The test section for each design was one track mile. To September 1, 1947 the test joints had carried 139 million gross tons of traffic. Since 1937 only minor track maintenance has been required on the 9 miles of test track, and none of the test sections has been replaced with new bars.

Joint Droop and Rail Batter

Measurements of joint camber and rail surface profiles to determine the degree to which abutting rail ends are being held in the same plane and the extent of rail joint batter were repeated this year as in previous years and the results are given in Figs. 1 and 2.

All designs of bars on the end-hardened south rail have maintained the rail ends with little droop or loss of camber. The receiving rail end has become lower than the leaving end due to joint bar wear on locations M, N, S, T and U. On the remain-

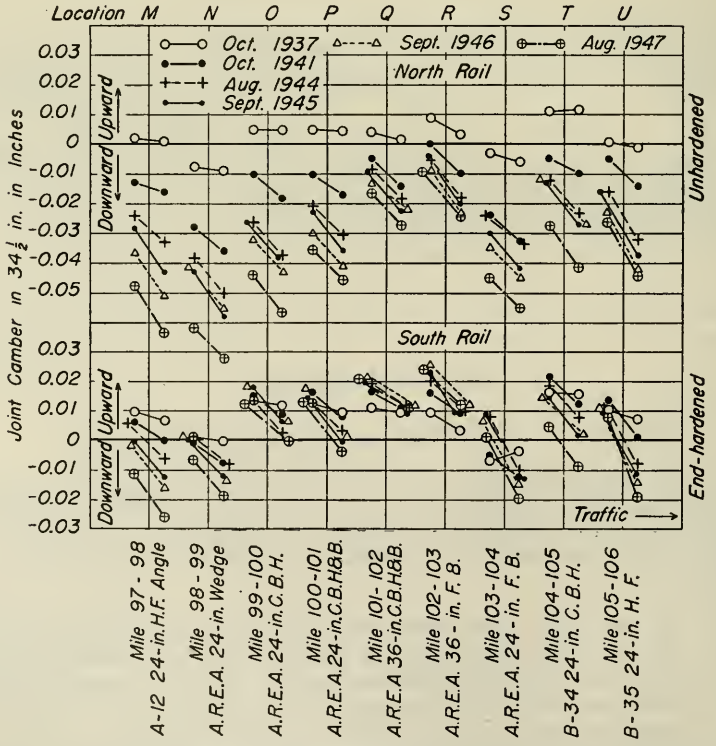


Fig. 1.—Joint Camber in 34½ in. at Leaving and Receiving 112-lb. RE Rail Ends for 60 Joints in Each Test Location on the Santa Fe for 1937, 1941, 1944, 1945, 1946 and 1947.

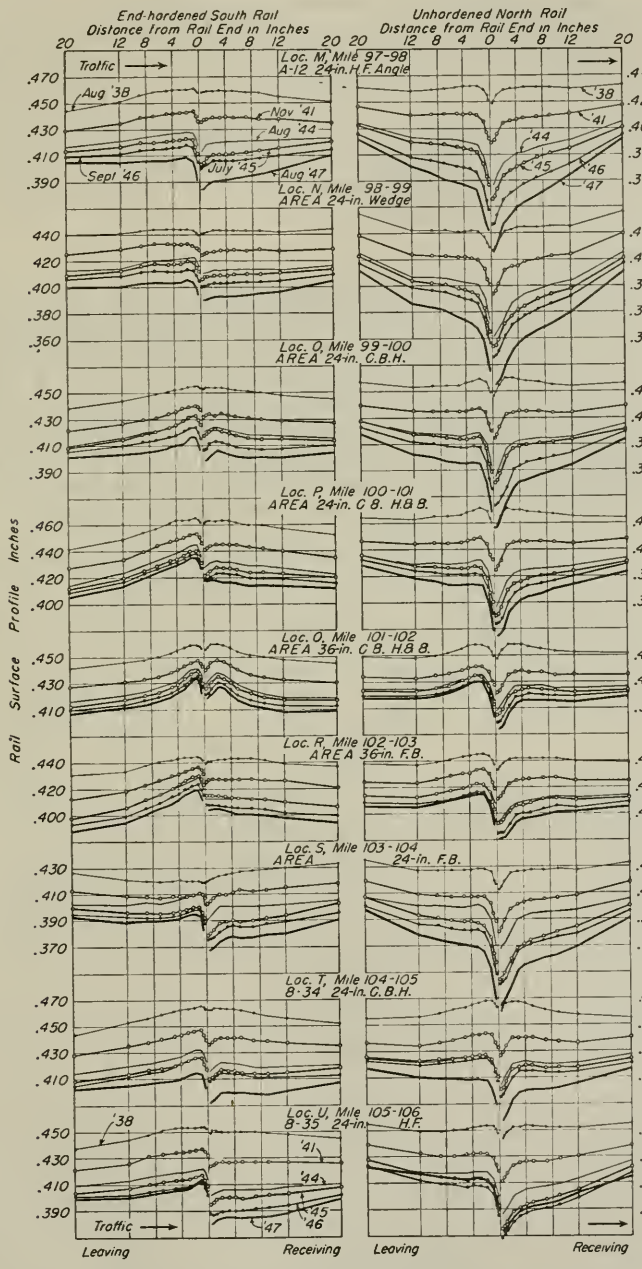


Fig. 2.—Rail Surface Profile for 1938, 1941, 1944, 1945, 1946 and 1947 on the Santa Fe; Average for 30 Joints in Each Location.

ing locations, precision grinding at the rail end would restore an excellent condition of surface. This is particularly true for locations Q and R with the 36-in. joint bars.

For the unhardened north rail, a considerable droop (loss in joint camber) and rail batter has developed at all test locations with 24-in. joint bars. The two locations with 36-in. bars are the only ones in which the droop and rail batter are small, the droop in these two locations being only about 40 percent as much as the average for the 24-in. bar locations. What might be considered excessive droop and batter have developed at locations M, N, O, and S, and these bars are considered to have reached the limit of their economic usefulness.

Wear of Joint Bars

Wear of joint bar and rail end fishing surfaces permits the two bars of a joint to move closer to the rail web. The change in out-to-out distance of the two bars of a joint is therefore a measure of joint bar wear and an indication of the life of the bar. The changes in the out-to-out distance between 1937 and 1947 are given in Table 1 for the various bar designs. The change at the mid-length of the bar is shown in Fig. 3. So far there are no particularly significant differences in the rate of inward movement for the various design of bars. The rate is still progressing with reasonable uniformity and there is no indication of the abrupt increase of inward movement shown in the Pennsylvania test when the bars had exhausted most of the available take-up.

TABLE 1.—AVERAGE CHANGE IN OUT-TO-OUT MEASUREMENTS ON JOINT BARS FROM 1937 TO 1947 IN EACH TEST LOCATION ON THE SANTA FE

Values are the combined movements of the two bars. Negative sign means movement towards rail. Each value is the average for 30 joints on each rail. Values are in inches.

Location and Type of Bar	*Rail*	*Top of Bars*			*Bottom of Bars*		
		Leaving End	*Mid Length*	*Receiving End*	*Leaving End*	*Mid Length*	*Receiving End*
			Traffic →			Traffic →	
M. Mile 97–98; A–12	N	—.06	—.06	—.06	—.15	—.16	—.16
24-in. H.F. angle	S	—.06	—.06	—.05	—.13	—.12	—.10
N. Mile 98–99; AREA	N	—.13	—.16	—.16	—.08	—.12	—.11
24-in. Wedge	S	—.13	—.14	—.12	—.10	—.10	—.07
O. Mile 99–100 AREA	N	—.18	—.19	—.21	—.14	—.15	—.16
24-in. C.B.H.	S	—.15	—.15	—.13	—.11	—.13	—.10
P. Mile 100–101; AREA	N	—.21	—.25	—.22	—.13	—.18	—.15
24-in. C.B.H. & B.	S	—.22	—.20	—.16	—.18	—.16	—.09
Q. Mile 101–102; AREA	N	—.13	—.19	—.15	—.08	—.15	—.09
36-in. C.B.H. & B.	S	—.13	—.16	—.16	—.08	—.12	—.10
R. Mile 102–103; AREA	N	—.11	—.17	—.14	—.07	—.15	—.09
36-in. F.B.	S	—.14	—.19	—.14	—.09	—.16	—.07
S. Mile 103–104; AREA	N	—.19	—.21	—.25	—.14	—.19	—.23
24-in. F.B.	S	—.27	—.23	—.21	—.22	—.18	—.18
T. Mile 104–105; B–34	N	—.26	—.24	—.20	—.19	—.19	—.14
24-in. C.B.H.	S	—.26	—.24	—.20	—.24	—.22	—.18
U. Mile 105–106; B–35	N	—.07	—.07	—.05	—.21	—.21	—.21
24-in. H.F.	S	—.13	—.08	—.03	—.31	—.23	—.16
Avg. 24-in. H.C.–N,O,P,S,T.	N & S	—.20	—.20	—.19	—.15	—.16	—.14
Avg. 36-in. H.C.–Q,R.	N & S	—.13	—.18	—.15	—.08	—.14	—.09
Avg. 24-in. H.F.–M,U.	N & S	—.08	—.07	—.05	—.20	—.18	—.16

F.B. = full bearing bars; C.B.H. & B. = controlled bearing bars head and base; C.B.H. = controlled bearing bars, head only; H.F. = headfree bars; H.C. = head contact bars.

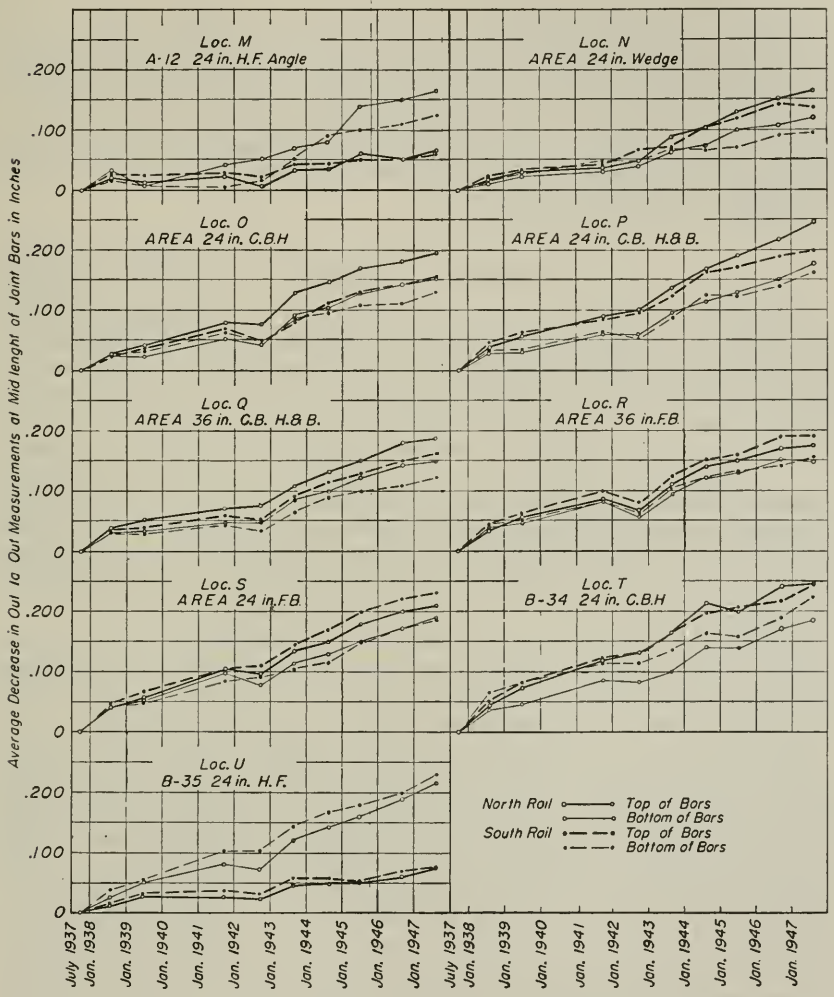


Fig. 3.—Average Annual Change in Out-to-Out Distances of Joint Bars for 60 Joints in Each Test Location on the Santa Fe; End-Hardened South Rail, Unhardened North Rail.

The maximum amount of theoretical "pull in" for the various types of head contact bars ranges from 0.38 in. to 0.50 in., but the upper radius of a bar will dig into the top of the upper web fillet at a considerably lesser movement. Bars with one or both ends bearing well against the upper web fillet of the rail were found in every Santa Fe location equipped with head contact bars; 60 joints at each of these locations were inspected in 1947. Results on the 36-in. length bars of locations Q and R were 13 and 6 percent of the bars against the upper fillet of the rail; and on the 24-in. bars of locations N, O, P, S and T the range was from 23 to 39 percent. There was no difference in this condition between the unhardened north rail and the end-hardened south rail.

Cracked Joint Bars on Santa Fe

In 1947, visual head cracks in 32 bars were counted in the mile of track on location O, AREA 24-in. controlled bearing bars head only, and cracks in 34 bars of location T, B-34 24-in. controlled bearing bars head only. These cracks were observed only in the head of the bars and near the rail ends. The number of cracked bars removed from service prior to 1947 is negligible except for location T which is now reported as 44 bars. In the 1946 inspection, locations other than O and T had only from 1 to 4 visually cracked bars per mile of track.

Pennsylvania Installation

Twelve different designs of joint bars for 131-lb. RE rail were placed in the eastbound main track of the Pennsylvania east of Valparaiso, Ind., in August 1937. The test section for each design comprised one-half track mile, and the installation was made in conjunction with laying new rail. The Evertite bars were removed from location L in April 1941, because they were no longer giving satisfactory service. The two test sections of 24-in. joint bars, locations B and E, were replaced in November 1943, after carrying 100 million gross tons of traffic. The AREA 36-in. full bearing bars of the north rail in location A, with the exception of 30 joints on which detailed measurements were being made, were removed from track in 1944. The 36-in. joint bars in the remaining test sections were all replaced in April 1947, after carrying 178 million gross tons of traffic. Complete data on final measurements were given in last year's report.

As the joint bars were removed, a careful inspection of each rail end was made in eight of the test sections (four miles of track). One small upper web fillet crack was found in one rail end; no cracks were found at any of the end bolt holes. The rail joints had no lubricant or corrosion retardant during or since their installation.

Only five joint bars were removed from track within the last three years due to cracks. As the worn bars were removed, they were inspected for cracks. All bar cracks found were in the top fishing surfaces near the rail ends; no bars were found cracked in the bottom fishing surfaces. Locations C, D, F, G and I had either none or only one or two cracked bars. Location H had five cracked bars. Location J, A-13 36-in. headfree angle bars, had seven cracked bars in the north rail and one cracked bar in the south rail. Location K, B-43 36-in. headfree bars had 32 cracked bars in the unhardened north rail and 16 cracked bars in the end-hardened south rail. Seventy percent of the cracks were at the receiving rail end of the bars. Cracked bars in the unhardened north rail numbered 48, and 19 were in the end-hardened south rail. Thirty-eight of the cracked bars were inner bars and 29 were outer bars.

Upon removal of the head contact bars it was found that many of them were touching the upper web fillet of the rail. None of the bars was touching the lower web fillet of the rail. For the various locations, the percent of joints with bars touching the upper fillet of the rail is given in Table 2. The bars so touching were determined by observation of the worn spots on the bars and the rails. Of the 408 joints inspected in the unhardened north rail, 60 percent had one or both bars of a joint touching the rail fillet. In the end-hardened south rail, 18 percent of the joints had one or both bars touching the rail fillet. Of the 306 joints with one or both bars touching the rail fillet, 46 percent had both bars touching, 51 percent had only the inner bar touching and 3 percent had only the outer bar touching. This indicates that more fishing wear occurs at the inner bar than at the outer bar of a rail joint. Of the 306 joints

TABLE 2.—WORN HEAD CONTACT JOINT BARS IN CONTACT WITH UPPER FILLET OF RAIL WEB IN TEST LOCATIONS ON THE PENNSYLVANIA

Percent of test joints with some point of top of one or both original bars in contact with upper web fillets of 131-lb. RE rail at time of removal of bars in April 1947 after 178 million gross tons of traffic.

Location and Type of Bar	*North Rail Unhardened Ends*	*South Rail End-Hardened*
C. B–19 36-in., F.B.	82	—
D. B–19 36-in., C.B.H. & B.	56	13
F. B–19 36-in., C.B.H.	84	49
G. F–4 36-in., F.B.	49	6
H. F–4 36-in., C.B.H. & B.	59	9
I. A–39 36-in., F.B. angle	32	12
Average	60	18

F.B. = full bearing bars; C.B.H. & B. = controlled bearing bars head and base; C.B.H. = controlled bearing bars head only.

found with one or both bars touching the rail fillet, 89 per cent of the bars were touching the rail fillet at and near the rail ends and may have been touching at other places along the bar; only 11 percent of the bars were touching at one or both ends only of the bars.

At the only two locations with angle bar sections, it was found that the under side of the bottom of the extending base flange of some of the angle bars was wearing into the shoulders of the special two-tie joint plates applied to the joint ties at only these two locations. For these two angle bar sections originally there was clearance over the top of the heavy shoulders of the Pennsylvania special two-tie joint plates. In location I, A–39 36-in. full bearing angle bars, 10 joints had one or both angle bars wearing into the shoulders of the joint plates. In location J, A-13 36-in. headfree angle bars, 89 percent of the joints in the unhardened north rail and 65 percent of the joints in the end-hardened south rail had one or both angle bars wearing into the shoulders of the joint plates. Location J had a high rating in service performance through 1944, but since then had deteriorated badly. It is probable that the deterioration was influenced by contact between the joint bars and the joint plate shoulders on over three-fourths of the joints.

The Backes rail fishing height gage was used on the rail ends of six joints at each location. For locations C, D, F, G, H and I equipped with head contact bars, the rail fishing height at 1 in. from the rail ends was worn from 0.020 to 0.060 in. as compared with the existing fishing height of the same rail away from the joint bars. On the end-hardened south rail the average fishing height wear 1 in. from the rail end was 0.028 in., and on the unhardened north rail the average wear was 0.035 in. There was more fishing wear on the receiving rail ends than on the leaving rail ends. There was considerably more fishing wear on the rail ends behind the inner bar than behind the outer bar of a joint.

It is of interest to see what effect the new F–7 36-in. full bearing head contact bars produced on the camber of the test joints. Average joint camber values taken in August 1947 are shown in Fig. 4 for the new joint bars and may be compared with values obtained with the original joint bars from 1937 to 1946. For the unhardened north rail, the joint camber values with the new bars are brought back up towards the original values of 1937. A considerable rail end batter had occurred on these un-

hardened rail ends which the new bars could not restore, but the new bars eliminated the droop of the joints. For the end-hardened south rail, the decrease in joint camber in all nine locations still in service until April 1947 has been inconsiderable—which is probably due to the small amount of rail end batter. The August 1947 camber values of Fig. 4 show that these joints in the end-hardened south rail were well restored by the application of the new bars. The play between the worn fishing surfaces of the rail and the old bars was evidently taken up by the new bars, and the small droop of the joints was also largely corrected.

Rail surface profiles were also obtained in August 1947 on these joints equipped with the new bars. Rail surface profiles as previously plotted with rail surface wear included, obscured the profile over the new bars. Therefore, in Fig. 5 the rail head wear was omitted, and profiles over the original bars for 1938 and 1946 are compared with the profiles for 1947 to see how effective the new bars are in restoring the rail joint surface. For the end-hardened south rail, the new bars have provided satis-

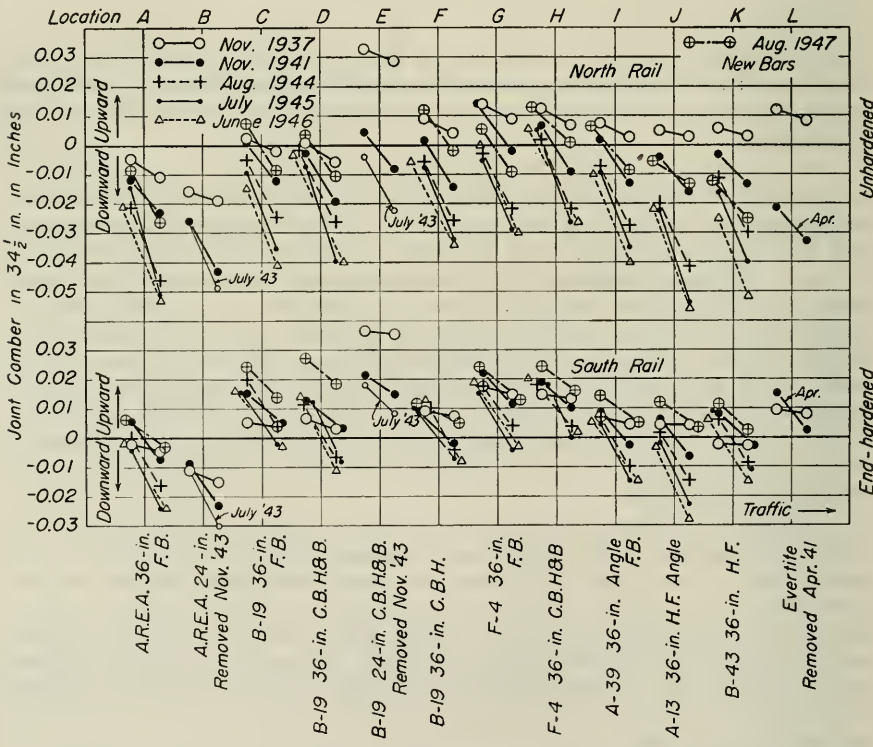


Fig. 4.—Joint Camber in 34½ in. at Leaving and Receiving 131-lb. RE Rail Ends for 60 Joints in Each Test Location on the Pennsylvania with Original Bars for 1937, 1941, 1944, 1945 and 1946 and with New Bars for 1947.

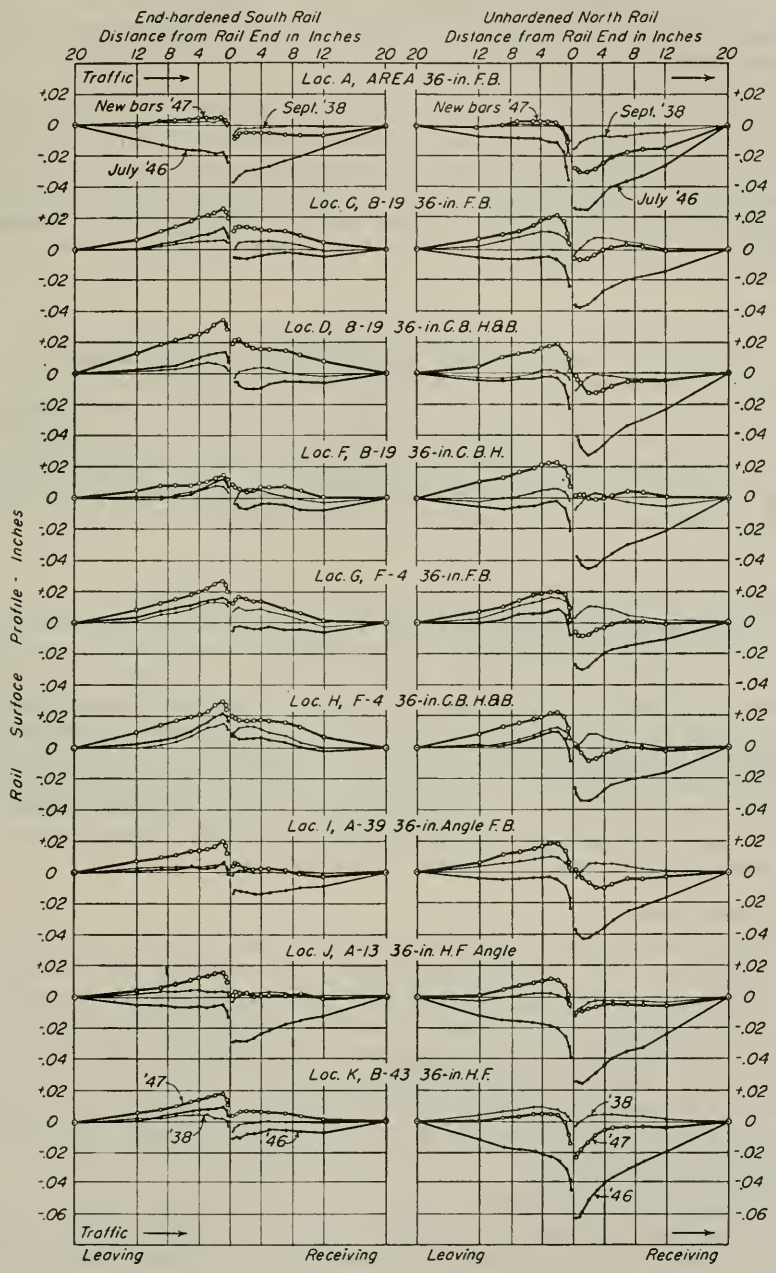


Fig. 5.—Rail Surface Profiles with Original Bars for 1938 and 1946 and with New Bars for 1947 on the Pennsylvania; Average for 30 Joints in Each Location.

factory rail surface profiles with only a small amount of batter at the rail end. At all locations the surface at the rail ends is high but it is not considered high enough to be objectional.

For the Pennslyvania unhardened north rail, the average rail surface profiles with the new bars for the leaving rail end of 8 of the 9 locations are above the original profiles of 1938. An average rail end batter of from 0.02 to 0.03 in. has occurred on these unhardened rail ends which the new bars could not restore. The new bars have also taken up much of the fishing surface wear at the rail ends because the step between the leaving and receiving rail ends has been reduced in the 1947 profile as compared with the 1946 profile. Probably all of this step in the 1947 profiles is due to rail end batter.

Conclusions

The service tests have consisted of the installation on tangent track in 1937 of 9 different types of joint bars for 112-lb. RE rail on the Santa Fe, all of which are still in track after 139 million gross tons of traffic; and 12 different types of joint bars for 131-lb. RE rail on the Pennsylvania, the last 9 types being removed in April 1947, after 178 million gross tons of traffic. Periodic inspection and measurements of certain characteristics which are judged to be indicative of service performance of the various types of joint bars have been made. The following conclusions seem justified by the results to date.

End-Hardened Rails

The entire service performance of all the various types of joints on the end-hardened rails for both the Santa Fe and Pennsylvania is outstandingly superior to that on the opposite unhardened rails. Not only has the rail end batter been reduced by the end-hardening, but in addition the service life of the joint bars has been substantially prolonged. New bars recently necessary on the Pennsylvania test rail locations produced an excellent rail surface profile on the end-hardened rail, but the new bars could not remove a considerable rail end batter on the unhardened rails. From the tests it can be concluded that proper rail end-hardening will very materially increase rail life on tangent track and that it will also materially increase the service performance of the entire rail joint regardless of the type of joint bars used.

Rail Head Wear

The rail head wear at a point 20 in. from the rail end of the 112-lb. RE rails on the tangent track of the Santa Fe averages 0.039 in. for 129 million gross tons of traffic. The corresponding wear on the 131-lb. RE rails of the Pennsylvania averages 0.045 in. for 174 million gross tons of traffic. These low rates of rail head wear (0.030 in. for the 112-lb. RE rail and 0.026 in. for the 131-lb. RE rail per 100 million gross tons of traffic) mean that these rails should not have to be removed from tangent track for many years due to rail head wear. As would be expected no difference was observed in the rate of rail wear beyond the rail joint with the various types of bars.

Length of Joint Bars

The relative service performance on the Pennsylvania indicates that the service life of 36-in. bars is 1.8 times that of 24-in. bars in the same track in terms of gross tons of traffic carried. On the Santa Fe the results show that a longer service life may be expected for unhardened rail when equipped with the longer joint bars. The data show that the two locations with 36-in. bars provide a much smoother riding surface after 10 years of service.

It seems evident from both the Pennsylvania and Santa Fe tests that compared to the 24-in. bars, the 36-in. bars will have a substantially longer service life, maintain a better track surface at the joints, and most important—prolong the life of the rail itself.

Controlled Bearing Bars

The performance of full bearing head contact bars has been equal to or better than the controlled bearing head and base bars of similar design. The controlled bearing head only bars of locations O and T on the Santa Fe are developing a significant number of head cracks.

Headfree Bars

The performance of headfree bars is as good as the average performance of head contact bars of comparable section and length.

Angle Bars

Although there are some differences in the relative performance of the different designs of angle bars included in the test, in general the short toe designs of bar are giving equal or superior performance.

Section Area of Bars

In the Pennsylvania installation the relatively light weight section F-4 bar (locations G and H) gave fully as good or better performance than the other much heavier bars.

Special Types of Joints

The special types of joints included in the tests (The Evertite joints in the Pennsylvania installation and the wedge type joints in the Santa Fe) have not given as good service as the conventional types of rail joints.

Report on Assignment 8

Joint Bar Wear and Failures; Revision of Design and Specification for New Bars and Bars for Maintenance Repairs

Ray McBrian (chairman, subcommittee), J. B. Akers, W. C. Barnes, C. B. Bronson, W. J. Burton, C. M. Chumley, C. J. Code, L. S. Crane, P. O. Ferris, F. S. Hewes, S. R. Hursh, G. M. Magee, E. E. Mayo, C. E. Morgan, R. A. Morrison, L. T. Nuckols, R. E. Patterson, W. C. Perkins, J. C. Ryan, R. T. Scholes, W. D. Simpson, J. G. Wishart.

A progress report of the rolling-load tests of joint bars being conducted at the University of Illinois under the direction of R. S. Jensen is submitted as information in Appendix 8-a which follows:

Appendix 8–a

Sixth Progress Report of the Rolling-Load Tests of Joint Bars

By R. S. Jensen

Special Research Associate of Engineering Materials, University of Illinois

Introduction and Acknowledgment

This is a report on the tests of joint bars conducted during the past year in the Talbot Laboratory, University of Illinois, as a part of the work of the Engineering Experiment Station in cooperation with the American Railway Engineering Association Committee on Rail. Ray McBrian, engineer of standards and research, Denver & Rio Grande Western Railroad, is chairman of the subcommittee for this assignment. The work is sponsored and financed by the Association of American Railroads.

Acknowledgment is made of the services of Lewis Franklin and Elmer Hunt, mechanicians in the Talbot Laboratory shops, and Paul Andrews and Norman Block, student test assistants. A large part of this work had been carried on by the late Professor N. J. Alleman, who formerly conducted and supervised these tests.

Testing Machines and Test Specimens

Joint bar tests were made in three 33-in. stroke rolling machines similar to one described in the Proceedings, Vol. 40, 1939, page 649. The dimensions of the test joint and method of loading are described in the Proceedings, Vol. 44, 1943, page 587. In all tests the maximum bar bending stresses are obtained with the wheel load at the joint gap and are 50 percent in value and reversed in sign with the wheel load at the cantilever end of the stroke.

Results are reported on 3 tests of 115–K4 bars and 10 tests of 131–AREA bars, together with 2 tests of 112–K16 bars and one test of 131–K14 bars which had not been completed at the writing of last year's report. Also, 9 joints of 115–HF 36-in. bars with special bolt hole spacing were tested.

Table 1 lists the chemical analyses and Table 2 the physical properties of heats from which the bars were obtained as supplied by the manufacturers.

Table 1.—Chemical Analyses of Joint Bars

Bar Type	Length in.	Heat No	Serial No.	Chemical Composition				
				C	Mn	P	S	Si
131–K14–HF	24	6368	19	0.46	0.55	0.013	0.027	0.10
112–K16–HF	36	920761	11	0.45	0.61	0.017	0.024	0.08
115–K4–HF	24	5–309	1	0.47	0.67	0.018	0.034	0.12
115–HF Special	36	4–010	40	0.45	0.68	0.016	0.032	0.15
131–AREA FB	36	4908	36	0.49	0.63	0.013	0.029	0.14
131–AREA FB	36	5859	38	0.45	0.60	0.016	0.027	0.14
131–AREA FB	36	5860	41	0.47	0.67	0.010	0.024	0.15
131–AREA FB	36	8335	42	0.38	0.73	0.015	0.028	0.12
131–AREA FB	36	3962	43	0.42	0.75	0.022	0.032	0.15
131–AREA FB	36	10661	44	0.47	0.65	0.014	0.028	0.12
131–AREA FB	36	12945	45	0.46	0.61	0.015	0.028	0.14

TABLE 2.—PHYSICAL PROPERTIES OF JOINT BARS

Bar Type	Serial Number	Tensile Strength psi.	Yield Point psi.	Red. of Area percent	Elongation 2-in. gage percent
131–K14–HF	19	111,700	76,070	46.3	22.0
112–K16–HF	11	115,900	81,400	43.4	19.0
115–K4–HF	1	128,850	76,100	31.0	14.0
115–HF Special	40	122,950	84,600	39.0	18.0
131–AREA FB	36	114,550	74,250	35.8	18.0
131–AREA FB	38	110,400	73.120	46.3	20.0
131–AREA FB	41	120,100	77.400	40.8	20.0
131–AREA FB	42	124,080	81,180	48.3	20.0
131–AREA FB	43	113.100	74,820	46.3	20.5
131–AREA FB	44	124,450	82,020	41.8	23.0
131–AREA FB	45	118,500	77,150	44.8	21.0

Results of Rolling-Load Tests

Data on the 25 joints tested since the previous report was published are tabulated in Table 3. For all tests, bolt tension was set and maintained at 15,000 lb. in the heat-treated prestressed bolts, and periodic checks were made as the tests progressed. The criterion for bar failure is taken to be the number of cycles of loading to propagate a fatigue crack to half of the bar height and the cycles for failure are so recorded for each joint in Table 3. The Brinell hardness tabulated is the value obtained on the fishing surface of the bar which failed. Also in the table, the condition of the rail ends is noted, "C" for cold-sawed and "H" for hot-sawed. Cold-sawed rail ends were formed by sawing a single length of rail, thereby reducing variations in rail fishing heights to a minimum. Hot-sawed rail ends in short lengths were obtained for the tests, and profiles were taken on the upper and lower fishing surfaces for all hot-sawed rail ends. For test joints with headfree bars, the upper fishing surface profile of the rail was taken in the upper web fillet. In the last column of Table 3 are listed the maximum heights of projections on the upper and lower rail fishing surfaces at the rail ends contacting the bar which failed. The projections result in a pinching action due to a reduction in fishing height over a short distance.

Hardness Tests on Joint Bars

Hardness readings were taken on upper and lower surfaces of both bars of each joint before testing. The Brinell test with 3000-kg. load and 10-mm. (0.3937 in.) ball gives a good indication of bar strength, but does not accurately portray the condition of the surface. In repeated stress tests the surface carries the highest bending stress, and bar fatigue strength is influenced greatly by the strength of the bar surface, by decarburization, etc. Accordingly, Rockwell B tests, 100-kg. load, 1/16-in. ball, were made on all bars tested this year. This test is more sensitive to surface condition and presents a more accurate picture of surface hardness. The average of five readings on each bar surface was converted to "equivalent Brinell hardness" for comparison with Brinell hardness values.

All Rockwell, or equivalent Brinell, readings were lower than the corresponding Brinell readings. The minimum difference of five points was found on the top surface of the south bar of joint 111 and a maximum of 97 points difference was noted on the lower surface of the south bar of joint 131. The low Rockwell hardness as compared to the Brinell hardness indicates that the bar surfaces are decarburized, some bars more

TABLE 3.—ROLLING-LOAD TESTS ON JOINT BARS

Maximum positive bending moment: 44,400-lb. load—400,000 in.-lb.; 55,500-lb. load—500,000 in.-lb.
Maximum negative bending moment is 50 percent of positive moment.
Bolt tension: 15,000 lb. Bolts: 1 in. and 1⅛ in. diameter, heat-treated, prestressed.

Joint No.	Wheel Load lb.	Cycles for Failure	Bar Failure N—North S—South	Hardness on Failed Bar BHN	Surface Hardness Equiv. BHN*	Rail Ends H—Hot Sawed C—Cold Sawed	Pinching on Failed Bar in.	
							Top	Base
			Bars: 131–K14 HF 24-in. Serial 19					
106	44, 400	1, 055, 300	Top S, ¾ in. from rail end	207		C		
			Bars: 112–K16 HF 36 in. Serial 11					
107	44, 400	390, 900	Top N, rail end	207		C		
108	44, 400	402, 000	Base S, to bolt hole	240		C		
		Avg. 396, 450						
			Bars: 115–K4 HF 24-in. Serial 1					
109	44, 400	2, 000, 000	No failure—top crack N	206	160	C		
110	44, 400	2, 000, 000	No failure—top crack S	196	165	C		
113	44, 400	334, 900	Base S, to hole	209	167	C		
		Avg. 1, 445, 000						
			Bars: 131–AREA FB 36-in. Serial: Various					
111	55, 500	1, 030, 800	Base N, to hole	225	194	C		
112	55, 500	689, 000	Base S, gap to hole	231	171	C		
114	55, 500	573, 500	Base to hole, both bars	229–240	203–206	C		
118	55, 500	484, 600	Base S, and hole	247	202	C		
		Avg. 694, 500						
119	55, 500	328, 600	Base N, rail end	245	187	H	0.007	0.005
120	55, 500	623, 900	Base N, rail end	255	229	H	0.030	0.018
121	55, 500	497, 200	Base N, to hole	266	234	H	0.006	0.006
122	55, 500	872, 700	Base S, rail end	268	202	H	0.007	0.007
		Avg. 580, 600						
130	44, 400	2, 000, 000	No failure	223–271	176–205	C		
131	44, 400	1, 863, 100	Base N, to hole	258	222	C		
		Avg. 1, 931, 500						

TABLE 3.—*Continued*

Bars: 115–HF 36-in. Serial: 40 Special

A1	115	44, 400	800, 600	Base S, 2 in. from rail end	231	205	H(milled)	0.007	0.003
A2	123	44, 400	440, 900	Base S, ¾ in. from rail end	224	216	H(milled)	0.002	0.002
A3	124	44, 400	359, 200	Base N, to hole	205	185	H(milled)	0.002	0.004
			Avg. 533, 600						
B1	116	44, 400	810, 500	Base S, to hole	241	190	H(milled)	0.002	0.003
B2	125	44, 400	492, 700	Base N, 2¾ in. from rail end	217	210	H(milled)	0.004	0.004
B3	127	44, 400	727, 700	Base N, to hole	227	195	H(milled)	0.004	0.003
			Avg. 677, 000						
C1	117	44, 400	1, 060, 800	Base S, 2½ in. from rail end	244	210	H(milled)	0.002	0.002
C2	126	44, 400	1, 081, 000	Base S, to hole	262	210	H(milled)	0.003	0.006
C3	129	44, 400	307, 500	Base N, ¾ in. from rail end	248	216	H(milled)	0.004	0.003
			Avg. 816, 400						

*Equiv. BHN is average of 5 Rockwell B readings converted to Brinell.

than others. The average Brinell reading on both top and bottom of all bars was 235, while the corresponding average of surface hardness or equivalent Brinell was 192. Based on tabulated values of Brinell hardness and tensile strength, this indicates that the surface strength as represented by the equivalent Brinell is 18 percent lower than the tensile strength as represented by the corresponding Brinell readings.

Tests on 131–K14 HF 24-in. Bars

The one test reported in Table 3 on 131–K14 24-in. bars was carried over from last year's program since this test was in progress at the time of writing the previous report. Joint 106, with cold-sawed rail ends, ran for 1,055,300 cycles at the 44,400-lb. wheel load before failure, making an average of 1,458,800 cycles for three joints of this type tested at the light wheel load.

Tests on 112–K16 HF 36-in. Bars

Of four tests last year on 112–K16 36-in. bars, the two with cold-sawed rail ends failed at a lower number of cycles than those with hot-sawed rail ends, consequently two tests, Joints 107 and 108 with cold-sawed rails, were repeated as a check. The results were substantially the same, since the average for the check tests was 396,450 cycles compared to 372,900 for last year's test.

Tests on 115–K4 HF 24-in. Bars

Joints 109 and 110 with 115–K4 bars assembled on cold-sawed rails ran 2 million cycles with no failure. On no other type of bar did 2 tests run for 2 million cycles without failure. Inspection of the bars after disassembly revealed a top surface crack on one bar of each joint. In each case the crack was located in a gouge mark caused by a rail end.

The third test, joint 113, failed after 334,900 cycles from a crack originating in an area of heavy bearing and galling on the lower surface 2 in. back from a rail end. The crack spread directly upward to a bolt hole. After disassembly of the joint a transverse crack ¾ in. long was found in a top surface rail end gouge mark on the unfailed bar. Hardness values were quite similar for all three joints so it is apparent that hardness variation can hardly account for the low cycles for the failure of joint 113. Lateral bar deflection readings were made at intervals during the progress of each test. The upper bar surfaces were elastically distorted inward at midlength no more than 0.0044 in. at 100,000 cycles. Lower flanges were elastically distorted inward at midlength 0.0155 in. on the north bar, and 0.010 in. on the south bar at the same cycle value. Lower flange deflections were about double the values found on the joints which did not fail. The lateral elastic deflection undoubtedly causes an increase of stress on the bar flanges over that due to pure bending.

Out-to-out measurements taken at periodic intervals indicate that for these bars, the lower flanges moved inward from 0.020 to 0.070 in. while the upper flanges changed only slightly, moving outward usually from 0.001 to 0.010 in.

In Fig. 1, the top bearing surfaces of joint 110 are shown. As in almost all tests, the bearing area is widest at the gap. Rail end gouging may be noted with attendant galling caused by high bearing pressures adjacent to the gouges. Bearing near the bar ends is not at the center of the ¾-in. head fillet radius but is removed about ¼ in. toward the top of the bar. The bar fishing height is slightly too high to match the rail fishing height, resulting in a not too accurate fit of the bars on the rails and deeper bar gouging than would be the case with well matched fishing heights. The rails and bars are commercial products rolled to commercial tolerances, and the variations in fit are probably no greater than may be expected.

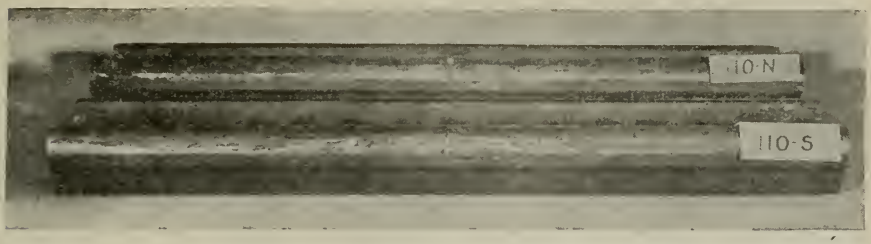


Fig. 1.—Top Surface Bearing on Bars of Joint 110. Bars: 115–K4, 4-hole, 24 in.

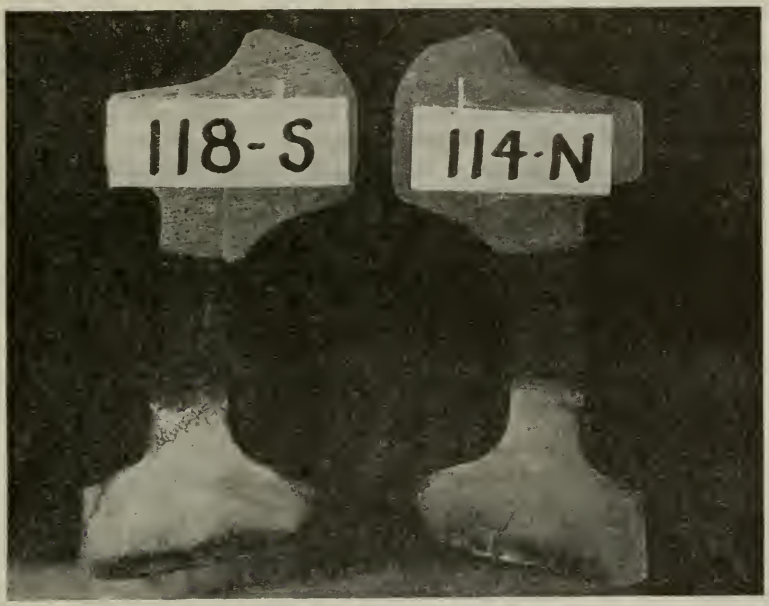


Fig. 2.—Fractures of 131–AREA Bars, Joints 114 and 118. Note that fatigue cracks started on lower fishing surfaces and at bolt holes.

The average of 1,445,000 cycles for the three tests of 115–K4 HF 24-in. bars is well above the averages of 684,500 cycles for five tests of 112–TR HF 24-in. bars and 543,900 cycles for four tests of 112–K16 HF 36-in. bars tested last year.

Rolling-Load Tests—131–AREA Bars

Table 3 gives the results of eight tests on the AREA bars at 55,500-lb. wheel load, four with cold-sawed rail ends and four with hot-sawed rail ends. The average number of cycles for failure using cold-sawed rails is found to be 694,500 cycles and for the hot-sawed rail tests the average is 580,600 cycles, amounting to a decrease of 16.4 percent. All bars failed on the lower surfaces from cracks formed at gouge marks at a rail end or directly beneath a bolt hole adjacent to a small area of heavy galling. Fractures of two bars, Fig. 2, show that cracks starting on the lower surface have progressed directly upward to meet cracks which have started at the bolt holes. Except

for the 115–K4 tests in which no bolt hole cracks were found this is the first lot of bars punched for 1⅛-in. bolts which have been tested.

In six of these eight tests at 55,500-lb. wheel load and in one of the two tests at 44,400-lb. wheel load the fatigue crack extended either to or toward the oval bolt hole, indicating that the weakening effect of this hole is greater than that of the round hole. Four of the broken bars disclosed fatigue areas at the bolt holes, 3 at oval holes and 1 at a round hole. Until more evidence is obtained it will not be definitely known if cracks originate at bolt holes due to the large size of hole, thus weakening the web of the bar, or to some other factor such as excessive gouging by the lock washers, etc. However, ¼-in. wire gages mounted in the lengthwise bar direction at the bottom of the central oval bolt holes adjacent to the outer bar surfaces indicate some stress due to bolt tightening, and stresses of the order of 15,000 psi. with gap loading of the joint.

Brinell readings on the failed flanges of the AREA bars with cold-sawed rail ends were quite similar, the range of hardness being 225 to 271. For the hot-sawed rail end tests the hardness range, 245–268, was not greatly different.

It seems reasonable to assume that if both bars of a joint fit the rails equally well the bars should then be equally stressed. However, if undue variations of fit occur one bar may carry the major portion of the load and consequently be highly overstressed. If the bars become stabilized and the stresses equalized before severe gouging, scuffing or galling take place, we may expect high cycles of failure from the joint; however, if a crack has been started we may expect early failure of the joint.

Lateral deflection readings, Table 5, were taken to be used as an indication of bar fit. The readings indicate the amount each bar flange has been pulled in laterally at midlength. Zero values were taken on the unstressed bars before assembly.

Table 4.—Lateral Bar Deflections on 131-AREA Bars at 100,000 Cycles

Values in Inches
Dial at center of 22-in. span

Joint No.	North Bar Flange		South Bar Flange		Average	
	Top	Bottom	Top	Bottom	Top	Bottom
111	0.0245	0.020	0.0148	0.0214	0.0196	0.0268
112	0.0075	0.0115	0.0189	0.0252	0.0132	0.0184
114	0.0244	0.0342	0.0196	0.0267	0.0220	0.0305
118	0.0072	0.0128	0.0014	0.0068	0.0106	0.0118
119	0.0088	0.0175	0.0067	0.0139	0.0078	0.0157
120	0.0145	0.0194	0.0100	0.0159	0.0123	0.0177
121	0.0144	0.0211	0.0190	0.0275	0.0167	0.0243
122	0.0096	0.0151	0.0116	0.0136	0.0106	0.0144

The deflections were largely elastic since the original readings were obtained after disassembly upon completion of each test. Elastic bending was greater on the lower flange than on the top flange in almost all cases. The average deflections of top and bottom flanges of both bars of each joint are listed in Table 4. For seven of the eight tests the lateral deflection values rank the performance of each joint (cycles for failure) correctly; the smaller the difference between upper and lower flange readings the higher the cycle value.

Individual values in Table 4 indicate a rather wide range of lateral deflections encountered in the bars even though well stabilized. Lateral bending appears to be influenced by many factors, including the profile of the unstressed bar, profile of rail fishing surface and bolt tension.

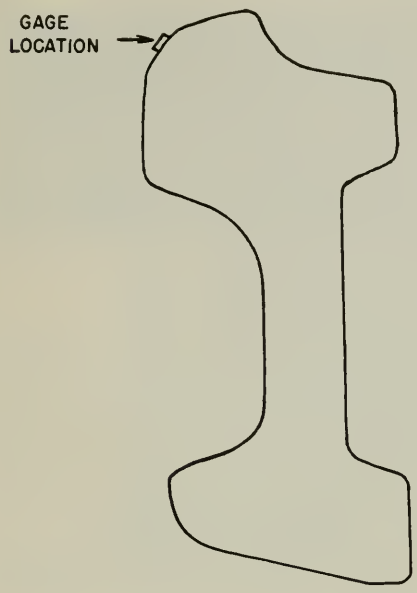


Fig. A.—Location of SR–4 gages on AREA bars, joint 111. Resulting strains, or equivalent stresses, are given in Table 5.

Comparing fatigue life of the 131–AREA bars with the 112–AREA bars, based on four tests of each with hot-sawed rail ends, the 131–AREA bars showed slightly greater fatigue life, averaging 580,600 cycles as against 427,900 for the 112–AREA bars.

Wire Strain Gage (SR–4) Tests

Wire strain gages were attached as shown in Fig. A to the beveled inner faces on the upper flanges of both bars of Joint 111, 36-in. 131–AREA bars. The ¼ in. gage-length SR–4 gages were placed in the longitudinal position so as to measure strains resulting from longitudinal bending. This position is removed ¼ in. from the nearest fishing surface contact and should be but little affected by local bearing pressure of the bar on the rail. Strain readings give a measure of the vertical and lateral bending stresses to which the bars are subjected.

TABLE 5.—STRESSES ON TOP FLANGES OF AREA BARS ADJACENT TO FISHING SURFACES
Joint 111 36-in. bars for 131-lb. rail

Bolts: 1⅛ in. Bolt Tension 15,000 lb. Cold-sawed rail ends

		Stress psi.	
	Cycles	*North Bar*	*South Bar*
Bolts tightened	0	+11,640	+10,950
Cantilever load	100	+16,740	+21,630
Load at joint gap	100	—26,200	—24,240
No load	100	+ 4,860	+ 8,910
No load-bolt tension reset	100	+ 6,600	+10,400
Cantilever load	30,000	+16,590	+17,430
Load at gap	30,000	—24,480	—23,310
No load	30,000	+ 5,550	+ 5,490
No load-bolt tension reset	30,000	+ 7,140	+ 6,330

(+) = Tensile stresses.
(—) = Compressive stresses.

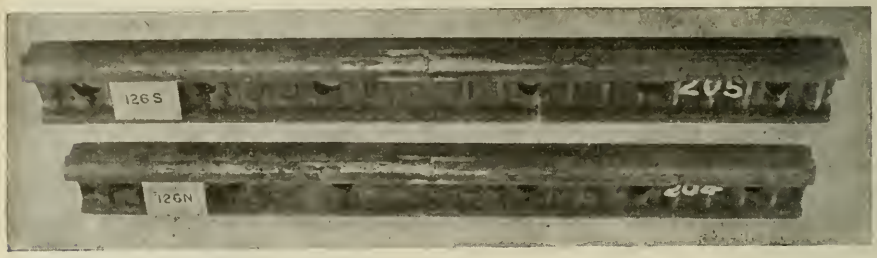


Fig. 3.—Top Bearing Areas of 115 HF 36-in. Bars of Joint 126 (Type C).

The results give a measure of the stress variations taking place as the bars become stabilized. The stresses were found to be quite similar on each bar after tightening the bolts; under the cantilever load at 100 cycles the south bar was taking the greater stress, while the gap loading stressed the bars almost equally. Removing the load after 100 cycles showed a decrease in stress from the zero cycle value of 58 percent on the north bar and 18 percent on the south bar. Resetting the bolt tension increased the stresses by about 1600 psi.

After 30,000 cycles of testing the bar stresses were found to be approximately equal. Stress differences exceeded 1000 psi. for only one load position, the load at the gap. Resetting the bolt tension at 30,000 cycles increased the stresses 1600 psi. and 800 psi., respectively.

This test indicates that bar stresses, unequal after joint assembly, tend to become uniform as a test progresses and the bars become stabilized. However, the initial stresses produced in lateral bending of the bars may tend to make fatigue failure more likely.

Two tests of 131–AREA 36-in. bars were made at the lighter wheel load of 44,400 lb. One test, joint 130, ran to 2,000,000 cycles without failure; the second test, joint 131, failed at 1,863,100 cycles from a crack starting at the base and progressing upward to an oval bolt hole. A fatigue area at the bolt hole measured approximately ½ in. downward from the hole at the outer surface of the bar, and ¼ in. at the inner bar surface.

Tests on 115–HF 36-in. Bars with Special Bolt Hole Spacings

Rolling-load tests were made on 9 joints of 115–HF 36-in. bars with special bolt hole spacings, as part of the work of Rail subcommittee on Assignment 12—Investigate recent developments affecting rail design. The results of these tests are included in the report of the research engineer (AAR) on Effect of Bolt Spacing on Rail Web Stresses within the Rail Joint, so only a brief summary of these tests will be made here. Three bolt hole spacings were used in the tests and three joints of each type were tested. The present AREA standard drilling, here designated as type A bars, had 5⅛-in. spacing between central holes and 6½-in. spacing between remaining holes; for type B bars the spacing was 7⅛ in. between central holes and 6 in. between remaining holes, and for type C bars 9⅛ in. between central holes and 5½ in. between remaining holes. Based on average cycles for failure, the tests indicate that increased fatigue life results from the greater spacing between central holes. All bars failed from cracks starting at the base; on 5 of the failed bars the cracks extended upward into bolt holes, and at 4 of these holes, 2 round and 2 oval, fatigue areas were observed. Bearing on the top fishing surfaces was heavy at the central section of the bars, and 6 of the 9 failed bars revealed hairline cracks from ⅜ in. to ¾ in. in length on the top surfaces of the bars, 5 occurring

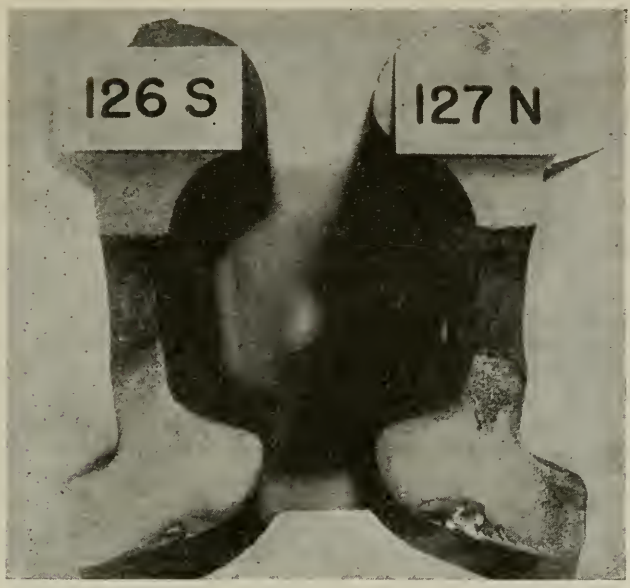


Fig. 4.—Fractures of Bars 126 S and 127 N. Note fatigue areas at bolt holes.

in gouge marks and one in an area of heavy bearing ¼ in. from a gouge mark. No cracks were found on the bottom fishing surfaces of the bars except the cracks which caused failure, all of these being in areas of heavy bearing and galling. Top surface bearing near the rail ends is wide on these bars due to the ¾-in. fillet radius. Fig. 3 shows the top bearing areas of the bars of joint 126, and is typical of the bearing areas for these 9 joints. Fractures of two of the bars are shown in Fig. 4, both bars showing fatigue areas at the bolt holes.

Summary

1. Rockwell B hardness tests, 100-kg. load on a 1/16-in. ball, on 22 bars gave readings considerably lower than standard Brinell values, and averages indicated that the surface strength of bars is lower by 18 percent than Brinell tests indicate.

2. Three rolling-load tests were made using 115–K4, 4-hole joint bars. Two tests gave excellent results as no failures were obtained at 2,000,000 cycles. The third joint failed after 334,900 cycles. The average for 115–K4 bars was well above the average for both the 112–TR HF 24-in. bars and 112–K16 HF 36-in. bars tested last year.

3. The average cycles for failure for four tests on 131–AREA 6-hole bars with cold-sawed rail ends was 694,500 as against 580,600 cycles for four tests with hot-sawed rail ends. For the same range of bar stresses the 131–AREA bars showed greater fatigue life than the 112–AREA bars.

4. On several AREA bars cracks were found which started at central bolt holes.

5. SR–4 strain gage tests on a pair of AREA bars indicate that bar stresses, although variable upon assembly of a joint, tend to become uniform after the bars are well stabilized at 30,000 cycles of testing. The initial stresses produced in lateral bending of the bars may tend to make fatigue failure more likely.

6. Tests on 9 pairs of 115–HF 36-in. bars with special bolt hole spacing indicate that longer fatigue life results from wider spacing of the central bolt holes.

Report on Assignment 9

Corrugated Rail—Causes and Remedy

Effect Upon Riding Qualities of Tracks and Upon the Costs of Track and Equipment Maintenance

Maro Johnson (chairman, subcommittee), S. E. Armstrong, W. C. Barnes, C. B. Bronson, E. E. Chapman, C. J. Code, J. L. Gressitt, S. R. Hursh, G. M. Magee, Ray McBrian, C. E. Morgan, R. A. Morrison, L. T. Nuckols, R. E. Patterson, E. F. Salisbury, F. S. Schwinn, F. W. Thompson, R. P. Winton, J. G. Wishart.

This is a progress report presented as information.

In his paper accompanying this report Professor Cramer describes the principal activity of the subcommittee during the past year. Included also are extracts from a letter written to Professor Cramer by E. Bennett of Sydney, Australia, civil engineer, New South Wales Railways, setting forth a theory in regard to slippage of wheels under cars; also an account of the formation and later disappearance of corrugation on a branch line of the Canadian National Railways received from Barton Wheelwright, chief engineer.

Extract from Letter of E. Bennett

Since corrugated rails are so wide-spread, at least in this state, I thought that slipping drivers did not provide a satisfactory answer but that some more general type of slip had to be sought.

All rolling stock wheels are coned to some degree, usually 1 in 20. If such a wheel is constrained to move in a straight line and it also makes a line contact with the rail, then at only one point on that line of contact can true rolling take place. At all other points there will be slipping.

However, as the wheel moves forward slipping cannot begin immediately because friction has to be overcome. In its forward motion therefore, elastic strains are set up in the tire and when the resultant stresses become greater then friction slippage commences. Immediately on the slipping surfaces being set in motion the force of friction drops to the dynamic value and there is a surplus force available for accelerating the strained part of the tire. Under suitable conditions the rubbing velocity between wheel and rail could be large enough to heat the rail above the critical temperature.

The above operation is cyclic and is a form of relaxation oscillation. It should be noted that the pitch of this kind of oscillation is independent of train speed. This is the only kind of oscillation whose pitch is so independent.

At the same time the wheel can oscillate in many other modes, bending torsion, compression, surface, etc. Each of these has its effect by modifying the pressure between the wheel and rail. At low speeds their main effect is to release the elastic forces in the tire at random periods usually before such forces can become large. Hence trains travelling at low speeds can have little effect on the formation of hard spots.

In a number of cases I have observed that trains at 40 mph. passing over corrugated rails have left small blue spots at the center of each shiny spot.

Factors which can affect relaxation oscillations as described above are:

(a) The coefficients of static and dynamic friction between the wheels and rails

(b) The cone angle of the wheel
(c) Wheel structure and carriage springing

It has been observed here that certain rails in a length do not corrugate. On investigation it has nearly always turned out that these rails were more ductile than the others. Probably this fact ties up with values of static and dynamic friction which produce only low velocities of slip.

Extract from Letter of Barton Wheelwright

Corrugated rail has not developed to any appreciable extent on the Canadian National Railways, and the only severe case we have had occurred on a relatively unimportant branch line 72.67 miles long connecting our Toronto-Montreal main line at Coteau with the main line of the Central Vermont Railway near St. Albans, Vt. It seemed to me unusual as this old line of railway, originally built about 1885, had always carried a relatively light and slow traffic. The corrugations developed rather suddenly, only on the south ten miles of this branch, though the traffic was similar throughout.

About 1912 on the section where the corrugations later developed, we laid part-worn 80-lb. ASCE rail, rolled in 1900. No corrugations developed in this rail. In 1924, 1925 and 1926 we relaid it with new 90-lb. rail and the corrugations developed about two years later.

The traffic was comparatively light, consisting of about four 2500-ton freight trains per day, hauled by Mikado locomotives having a tractive effort of 52,000 lb. and one local passenger train. The speed of all traffic was slow, from 30 to 35 mph. The line here passes through rolling and swampy country, alternating with low hills. The track was ballasted with ordinary pit-run gravel and cinders. The corrugations developed principally on tangent track, reached a peak about 1937, and since that date have gradually worn down.

We are now operating much heavier traffic over this line, consisting of four to six fast freights hauled by both Northern and Texas type locomotives with 57,000 lb. tractive effort, and a total weight of engine and tender of about 800,000 lb. Also our heavy Montreal–New York passenger trains are operated via this route. The speed is, however, still slow, under 40 mph., and the corrugations have not reappeared.

In responding to an inquiry as to what changes had occurred in physical or operating conditions at or prior to the time the corrugations began to disappear, Mr. Wheelwright mentions only increasing traffic.

The committee has had access to a record of experiments carried out about ten years ago by H. C. Mabie and submitted as a graduation thesis at the Massachusetts Institute of Technology. These tests were made by rolling circular discs of steel against each other. Corrugations were produced on the contract surfaces. The writer concludes that stress intensities of the order of those found between car wheels and rails will not produce corrugation in the rail under pure rolling contact, but that relatively small stress intensities will produce severe corrugation after a small number of repetitions of stress if there is slipping as well as rolling. However, in these tests the corrugations resulted from displacement of the metal rather than from the heating and quenching of the contact surfaces.

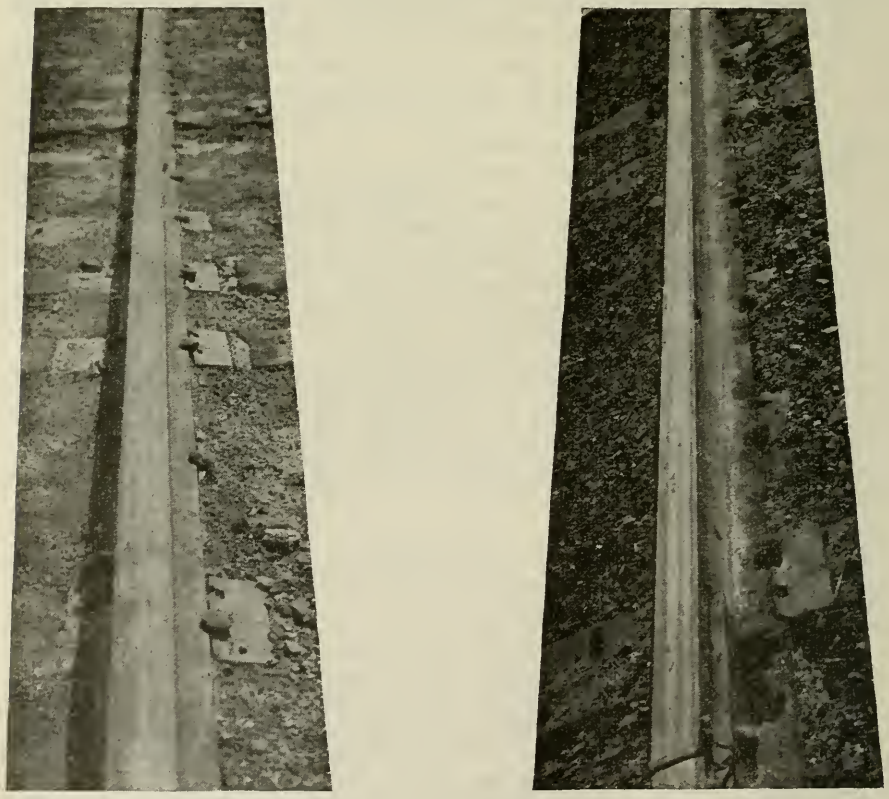
Third Progress Report on Corrugated Rails

By R. E. Cramer

Special Research Associate Professor of Engineering Materials, University of Illinois

The first report on corrugation was published in the Proceedings, Vol. 47, 1946, page 427; the second report was published in Vol. 48, 1947, page 729.

During the past year an attempt was made to produce corrugations in the side tracks of the Illinois Central Railroad at Champaign, Ill. A 6-driver locomotive was used pulling one loaded and one empty coal car and a caboose. Attempts were made to spin the drivers a part of a revolution while moving at slow speeds. Only continuous spinning was accomplished while the train was in motion. With the brakes of the cars set while standing, it was possible to spin the drivers only 2 or 3 revolutions. This produced wheel burns somewhat deeper than the thickness of the bright spots found



a b

Fig. 1.—Notches Ground in Rail.

(a) Notches were ground in this rail and a locomotive spun its drivers the full length of rail.

(b) Same rail after 3 months of heavy freight traffic. Typical corrugation has not developed.

in most corrugated rails. It was judged from these tests that slipping a driver wheel ¼ to ½ revolution would produce hard spots 0.002 in. to 0.005 in. in depth as found in most corrugated rails.

Following a suggestion of one railroad engineer, notches were ground in one rail with the thought that they might start vibrations of the car wheels which would produce corrugations. The drivers of the locomotive were then spun the full length of the rail. This rail was then placed in a heavy freight traffic track where speeds are slow. Fig. 1 (a) shows the rail before placing in traffic and Fig. 1 (b) after three months' service. There is a continuous hard and bright streak on the rail, but typical corrugation has not developed.

Further microscopic examination of the hard bright spots of corrugations has convinced the writer that they were formed by the steel being heated to a red hot temperature above the recrystallizing temperature of rail steel, followed by fast cooling from the large mass of metal in the rail head. Such heating of the rails would not be caused by short slides of car wheels during breaking. Short slips of a locomotive driver could develop the heat necessary to recrystallize the metal and form the hard spots of corrugations.

It has been reported that corrugations occur where trains slow down to conform to speed restrictions on curves ahead and for this reason the braking action has been considered to be responsible for the corrugations. It should also be considered that in these same locations the locomotive engineers start applying steam to pick up lost speed and this may cause some slipping of the driving wheels.

It has also been reported that, on locomotives operating under high steam pressure, quarter flat spots have been developed on driver tires, which are attributed to slipping of the drivers during the first part of the cylinder stroke. This may be a clue to how corrugations are formed in long stretches of tangent track after many years of service. Any further information on the slipping of locomotive drivers would be of considerable value to the committee studying the cause of rail corrugations.

Report on Assignment 10

Development and Characteristics of Fractures Under Engine Burns in Rail

Together with Investigation as to the Effectiveness of Welding Up Engine Burns by Oxyacetylene or Electric Methods

J. B. Akers (chairman, subcommittee), J. E. Armstrong, W. C. Barnes, C. H. Blackman, C. B. Bronson, E. E. Chapman, C. M. Chumley, H. R. Clarke, C. J. Code, L. S. Crane, G. W. Harris, C. B. Harveson, Maro Johnson, F. R. Layng, H. S. Loeffler, G. M. Magee, L. T. Nuckols, E. E. Oviatt, W. C. Perkins, G. A. Phillips, J. G. Roney, R. T. Scholes, F. S. Schwinn, G. L. Smith, F. W. Thompson, E. C. Vandenburgh, R. P. Winton.

This is a progress report offered as information.

A progress report of the rolling-load tests being conducted at the Southern Railway Laboratory at Alexandria, Va., is submitted herewith as information.

Appendix 10–a

Progress Report of Rolling-Load Tests on Engine-Burned Rails

Introduction and Acknowledgement

Rolling-load tests on engine-burned rails are being continued in the Southern Railway Laboratory at Alexandria, Va., with one 7-in. stroke machine loaned by the Sperry Products Corporation and one 12-in. stroke machine loaned by the Union Carbide & Carbon Laboratories. An additional machine purchased by the Association of American Railroads has recently been placed in service. Acknowledgment is also made of part-time use of one 12-in. stroke machine located in the Metal & Thermit Research Laboratory, Rahway, N. J., and the help of A. R. Ciuffreda, research engineer of that company, under whose immediate direction the work has been conducted.

Rolling-Load Tests, Test Specimens and Results

A previous report of results obtained was outlined in the AREA Proceedings, Vol. 48, 1947, page 734. A description was given of the various types of specimens being tested.

Since the previous report, 32 additional specimens have been tested and a summary of all test reports to date is listed in Table 1. Figs. 1, 2, 3 and 4 summarize the test results by types of specimen and by type of machine. In addition, the specimens obtained from control cooled rail have been shown separately.

Figs. 1 and 2, representing test results obtained on non-control cooled specimens selected from track, are inconclusive. It is believed that this is due to the fact that

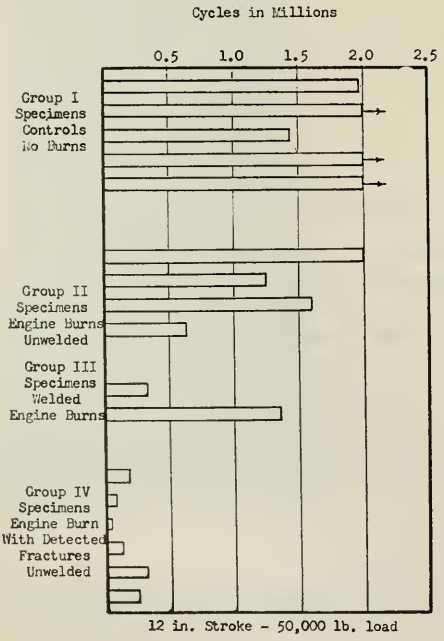


Fig. 1.—Summary of Rolling-Load Tests—Rails Selected from Track Nos. 1 Through 28.

TABLE 1.—RECORD OF ROLLING-LOAD TESTS

For report of tests on Rails No. 1 to 37 incl., see Proceedings, Vol. 48, 1947, pages 737–738.

Rail Test No.	*Description of Specimen*	*Load and Stroke of Rolling-Load Machine* b. in.	*Cycles to Failure*	*Remarks or Type of Failure*
38	Engine burned, flame cleaned and gas welded.	50, 000—12	2, 000, 000 No failure	Test discontinued
39	Engine burned, flame cleaned and gas welded.	60, 000— 7	1, 594, 200	Progressive from base of welded zone.*
40	Engine burned, flame cleaned and gas welded.	50, 000—12	601, 300	Failed progressively due to surface defect. See Note No. 1.
41	Engine burned without fracture, no repair.	60, 000— 7	2, 300, 000 No failure	Test discontinued.
42	Engine burned, flame cleaned and gas welded.	50, 000—12	274, 900	Failed progressively due to surface defect. See Note No. 1.
43	Engine burned, flame cleaned and gas welded.	60, 000— 7	2, 103, 000 No failure	Test discontinued.
44	Engine burned without fracture, no repair.	50, 000—12	864, 100	Failed progressively due to surface defect. See Note No. 1.
45	Engine burned, without fracture, no repair.	60, 000— 7	994, 600	Progression of engine burn.
46	Engine burned, without fracture, no repair.	50, 000—12	906, 900	Progression of engine burn.
47	Engine burned, without fracture, no repair.	50, 000—12	383, 300	Progression of engine burn.
48	Engine burned, without fracture, no repair.	60, 000— 7	2, 038, 100 No failure	Test discontinued.
49	Engine burned, without fracture, no repair.	60, 000— 7	2, 101, 300 No failure	Test discontinued.
51	Engine burned, without fracture, no repair.	60, 000— 7	2, 076, 900 No failure	Test discontinued.
53	Clear—(Control test)	60, 000— 7	2, 049, 900 No failure	Test discontinued.
56	Engine burned, without fracture, gas welded.	60, 000— 7	2, 019, 500 No failure	Test discontinued.
60	Engine burned, without fracture, gas welded.	60, 000— 7	541, 700	Progressive, originating at surface of rail outside welded zone.
61	Engine burned, without fracture, gas welded.	50, 000—12	1, 725, 100	Progressive, originating in heat stamping in web of rail.
66	Engine burned, flame cleaned and gas welded.	60, 000— 7	254, 100	Progressive, originating at surface of rail outside welded zone.
70	Engine burned, without fracture, no repair.	50, 000—12	2, 221, 500	Failed progressively from crack originating in head and web fillet.
71	Engine burned, without fracture, no repair.	60, 000— 7	2, 030, 000 No failure	Test discontinued.
72	Engine burned, flame cleaned and gas welded.	50, 000—12	906, 500	Progression of engine burn.
73	Engine burned, without fracture, no repair.	50, 000—12	1, 790, 400	Progression of engine burn.
74	Engine burned, without fracture, no repair.	60, 000— 7	2, 052, 000 No failure	Test discontinued.

TABLE 1.—RECORD OF ROLLING-LOAD TESTS—*Continued*

Rail Test No.	Description of Specimen	Load and Stroke of Rolling-Load Machine lb. in.	Cycles to Failure	Remarks or Type of Failure
75	Engine burned, without fracture, no repair.	50, 000—12	100. 600	Progression of engine burn.
76	Engine burned, without fracture, no repair.	60, 000— 7	610, 700	Progression of engine burn.
77	Engine burned, without fracture, no repair.	60, 000— 7	311, 300	Progression of engine burn.
81[c]	Engine burned, without fracture, no repair.	50, 000—12	253, 700	Progression of engine burn.
82[c]	Engine burned, without fracture, no repair.	50, 000—12	540, 900	Progression of engine burn.
83[c]	Engine burned, without fracture, no repair.	50, 000—12	732, 200	Progression of engine burn.
84[c]	Engine burned, without fracture, no repair.	50, 000—12	340, 200	Progression of engine burn.
85[c]	Engine burned, without fracture, no repair.	50, 000—12	493, 500	Progression of engine burn.

[a]This rail failed from a stress concentration caused by a corrosion pit on surface of head. Rails had been stored out in the open for a considerable period of time prior to testing.

[b]This rail was originally tested as an engine burned rail with no fracture beneath the burn. On failure it was discovered that the rail had been previously welded and then engine burned over the weld. The rail is therefore, considered a welded rail.

[c]Tested at Metal & Thermit Laboratory.

[*]Failure due either to incomplete elimination of engine burned metal prior to welding or to thermal crack produced by the electric arc. This is only electric welded specimen tested.

Note No. 1.—Progressive fracture originating at surface of rail head in each case within 1″ of the end of the stroke at the support end.

Note No. 2.—Progressive fatigue failure originating in web of rail due to unrelieved stresses in zone of heat transition.

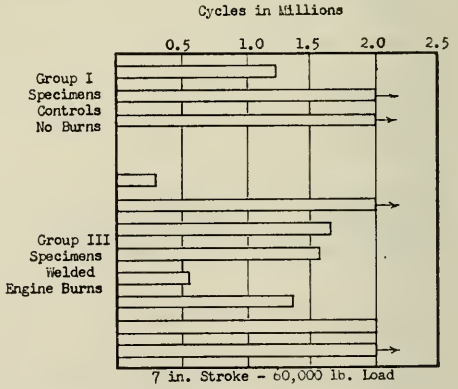


Fig. 2.—Summary of Rolling-Load Tests—Selected from Track Nos. 1 Through 28.

these specimens had various amounts of previous fatigue which, when supplemented by the additional fatigue in the rolling-load machines, created erratic results. Fig. 3, representing tests in the 7-in. stroke machine with intentionally engine-burned control cooled specimens indicates little, if any, difference between the number of cycles to

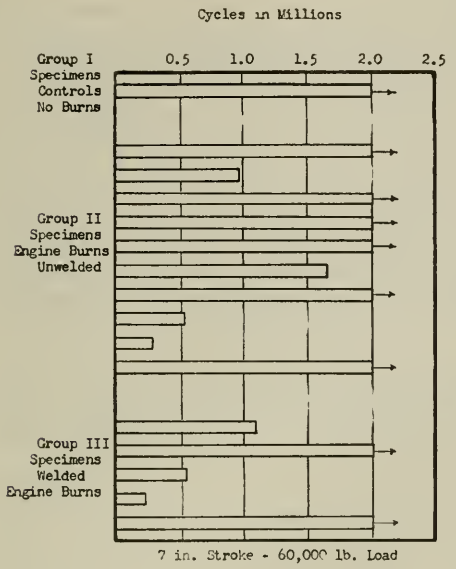


Fig. 3.—Summary of Rolling-Load Tests—Rails Burned Intentionally, Nos. 29 Through 85.

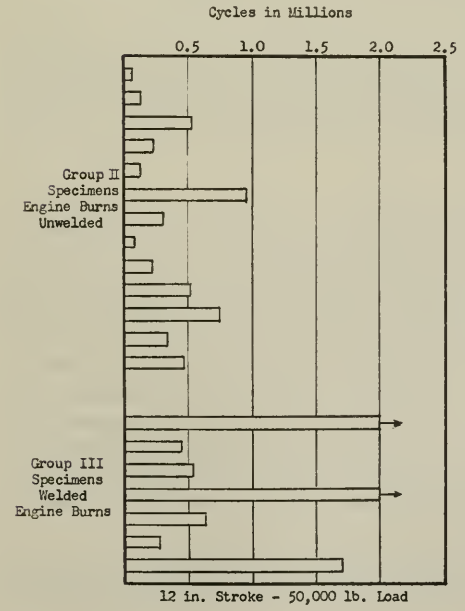


Fig. 4.—Summary of Rolling-Load Tests—Rails Burned Intentionally, Nos. 29 Through 85.

failure obtained with engine-burned rail as compared to rail free from defects. It is believed that this result is due to insufficient stress being developed in the test specimens under the conditions of test. It should be noted that the bending moment developed on the test specimen with the 7-in. stroke and 60,000-lb. load is 420,000 in.-lb. as compared with 600,000 in.-lb. developed on test specimens in the 12-in. stroke machine with a 50,000-lb. load. For this reason the conditions of test of the 7-in. stroke machine have been recently modified by increasing the load to 80,000 in.-lb. in order to bring the conditions of test between the two machines more nearly into line. Fig. 4 summarizes the results of tests on the intentionally engine-burned control cooled rail in the 12-in. stroke machine. The test results obtained, although limited, would appear to indicate a definite increase in fatigue life of engine-burned rails which have been repaired by welding as compared to engine-burned rails that are unrepaired. There is admittedly considerable scatter in the results obtained in the welded rails which is believed to be due to variations in welding technique.

Your committee proposes to continue these tests during the coming year and to augment them with an intensive metallurgical examination of the failed specimens in an effort to correlate the failures of welded engine burns with possible defects in the technique of welding repair.

Report on Assignment 11

Causes of Shelly Spots and Head Checks in Rail Surfaces; Develop Measures for Their Prevention

F. S. Hewes (chairman, subcommittee), S. E. Armstrong, W. C. Barnes, C. H. Blackman, C. B. Bronson, E. E. Chapman, Armstrong Chinn, C. J. Code, L. S. Crane, P. O. Ferris, J. L. Gressitt, G. F. Hand, C. B. Harveson, Maro Johnson, F. R. Layng, G. M. Magee, E. E. Mayo, Ray McBrian, R. J. Middleton, L. T. Nuckols, W. C. Perkins, G. A. Phillips, J. G. Roney, R. T. Scholes, I. H. Schram, G. L. Smith, Barton Wheelwright, R. P. Winton.

This report is offered as information.*

As explained in previous reports, the investigation is divided into four groups of subjects, the first being handled directly by the subcommittee, the second by the research staff of the Engineering Division, AAR, the third by the University of Illinois and the fourth by Battelle Memorial Institute. In general, this subdivision of the work has been continued during 1947. Funds are provided by the AAR for the work being done by Group 2 and jointly by the AAR and the manufacturers for Groups 3 and 4.

As the subcommittee continues its investigation and study of this subject, it has been unable as yet to find the solution, but the most promising developments so far appear to be the 3 percent chrome steel, the modified head contours and heat-treated rails. Field tests of many kinds have been made but some have not been in progress long enough to furnish conclusions. The following comments are offered relative to progress made so far, in the order of the groupings given above.

* The reports previously presented by this subcommittee appear in the Proceedings, Vol. 44, 1943, pp. 597–610; Vol. 45, 1944, pp. 446–469; Vol. 46, 1945, pp. 643–659; Vol. 47, 1946, pp. 432–448; and Vol. 48, 1947, pp. 750–766.

Group 1

Item (a).—A study of data submitted indicates no definite relationship between the chemistry and shelling, except insofar as the hardness of the running surface of the rail is affected.

Item (b).—A study of data submitted as to curvature, elevations, speeds and grades, reveals no definite trend.

Item (c).—The Delaware & Hudson ran a test on two similar curves, one with lubricators and the other without. This test was in progress about four years, but both curves developed shelling and flaking spots to approximately the same amount.

Item (d).—Experience on the Chicago, Milwaukee, St. Paul & Pacific and the Atchison, Topeka & Santa Fe indicates that transposing shelly high rails to the low rail, if done in time, is well worth while.

Item (e).—Tests on the Milwaukee, the Norfolk & Western, and the Pennsylvania have shown that rail slow-cold worked under traffic in non-shelling locations and relaid in shelling locations possesses very little, if any, greater resistance to shelling than ordinary rail.

Item (f).—The Norfolk & Western in May, June, and July 1941, laid in nine locations with curvature from 3 to 12 deg. where severe shelling of rail had been encountered, four heats of special high-carbon rail with carbon ranging from 0.84 to 0.91 percent, but otherwise conforming to usual specifications. The tests have been discontinued on seven of these locations, six due to shelling and one due to straight rail renewal. After six years' service in the remaining two locations, it appears that this high-carbon rail will not eliminate shelling but retards it more than ordinary carbon rail. However, the high-carbon rail has a tendency to head check and this in turn causes gage corner flaking or minute shelling. The sharpest curves did not flake or shell nearly as much as the lighter curves.

In April 1944 this railroad relaid in shelling territory fifteen 130-lb. PS rails that had been removed in an out-of-face rail renewal in other locations and which were normalized and had 1/32 in. machined from the head contour. These rails showed flaking and were removed after 1½ years' service.

This same road in August 1944 installed some 3 percent chromium rail, 131-lb. RE section, in shelling territory, on a 6-deg. curve. In April and July 1945, it installed five similar tests on 4, 5, 6 and 7-deg. curves. The rail in four of these locations is in excellent condition; one location is in good and another in fair condition. A few rails in the 7-deg. location have shelled. All locations have slight to medium flaking.

The Duluth, Missabe & Iron Range in April 1943, installed 112-lb. Lorain heat-treated rails on the high and low sides of half of a 4-deg. curve where shelling had been encountered. The other half was relaid at the same time with standard 112-lb rails. An adjoining 2-deg. curve was similarly handled but on the high rail only. For the 4-deg. curve, the heat-treated rails show slight checking and flaking; the standard rails were removed early in 1947 because of severe shelling. For the 2-deg. curve, the heat-treated rails show light flaking and checking, but no shelling. The standard rails were removed late in 1946 due to severe shelling.

The Pennsylvania in January 1946, laid on half of three curves of approximately 5 and 6 deg. in severe shelling territory, control cooled 131-lb. standard rails and on the other half, rails that were hot bed cooled. All of these rails were removed in 1947 and these tests indicate that both types of rail shell equally under corresponding conditions and shelling is not chargeable to control cooling.

Item (g).—Inspections have been made or reports received covering the general experience of the following roads during the year:

Norfolk & Western
Pennsylvania
Duluth, Missabe & Iron Range
Chesapeake & Ohio

Group 2

Part 2 of the assignment is covered by a report prepared by G. M. Magee, research engineer, which follows as Appendix 11–a (page 437) but attention is directed to the following additional remarks:

Item (a).—The Norfolk & Western in May and June 1942, laid at six locations of 2 to 12-deg. curvature, 131-lb. new rail with modified head contour where there had been considerable gage corner shelling. The modified section has a 7/16-in. gage corner radius, and a 12-in. head radius, these being connected by a 2½-in. radius easement curve. This contrasts with the standard dimensions of ⅜, 14 and 1 in. respectively. The modified section is retarding shelling slightly better than the standard.

The same road has a test of an equal number of new 131-lb. high-carbon rails and new 130-lb. PS rail installed in one location in December 1942, both high and low rails, where extensive shelling had been experienced in the past. The PS section has a head radius of 12-in. and a 7/16-in. corner radius, compared with those of the standard 131-lb. RE given directly above, and the head is a little deeper. The specifications were the same for both sections. Both sections have developed flaking and checking, but no shelling so far.

In fall of 1944 the Norfolk & Western installed a modified 131-lb. RE section in eight locations with curvatures from 2 to 8 deg. where there had been trouble with shelling. The modified section has a ⅜-in. gage corner radius and a 10-in. head radius, these being connected by a 1½-in. radius easement curve. The rail in two locations has been removed because of straight rail renewals. The modified section is retarding shelling slightly better than the standard.

The Pennsylvania in 1944 installed 152-lb. PS section rail with a modified head contour in four curves on heavy duty lines, in some portions of which there had been shelling. The modified section has a ⅜-in. gage corner radius, and an 8-in. head radius, these being connected by a ⅞-in. radius easement curve. These contrast with standard dimensions of ¼, 24 and 1 in., respectively. Two curves were relaid in 1947. These tests indicate there is some advantage of the modified head contour designed to better fit the worn wheel contour.

Item (e).—Shelling has been observed on rails laid on a 1:20 cant on the Norfolk & Western and on a 1:40 cant on the Chesapeake & Ohio. The Delaware & Hudson had a test of rail laid to both cants. No difference in shelling or flaking was observed.

The Norfolk & Western in March 1944 installed a test of new 131-lb. RE rail on tie plates with no cant, on a 4-deg. curve. The gage corner is severely checked and the rail is flaking.

Group 3

The third portion of the assignment is covered by a report prepared by Professor R. E. Cramer, which follows as Appendix 11–b (page 437).

Group 4

The fourth portion of the assignment is covered by a report prepared by H. A. Blank and G. K. Manning, which follows as Appendix 11–c (page 446).

Appendix 11–a

Field Investigation by Engineering Division Research Staff

The first three reports of the Engineering Division research staff included studies of rail and wheel contours and other track conditions that might have a bearing on the development of rail shelling. Modified rail head contours were designed and put in track and the results are being reported. The head corners have been somewhat lowered on the new 115, 132, and 133-lb. RE rail sections with the thought that shelling may be retarded thereby.

The last two years' reports describe rail stress measurements that developed information with respect to the magnitude of wheel loads and eccentricity of bearing coming on the outer rails of curved track.

Recently a rail head contour was designed to conform at the head corner to the throat of the average worn wheel contour. This corresponds to the head contour to which the outer rail on a curve tends to wear. The head corner is lowered considerably more than in the 115, 132, and 133-lb. RE designs. A few rails ground with this contour will soon be placed in a curve on the Norfolk & Western Railway to obtain further data on the shelling problem.

Appendix 11–b

Sixth Progress Report of the Shelly Rail Studies at the University of Illinois

By R. E. Cramer
Special Research Associate Professor of Engineering Materials, University of Illinois

Organization and Acknowledgment

The shelly rail studies at the University of Illinois are financed equally by the Association of American Railroads and the American Iron and Steel Institute Technical Committee on Rails.

The writer wishes to acknowledge the help of R. S. Jensen, special research associate, Proal Judson and Paul Krogdahl, student assistants, and Marion Moore, mechanician. Special acknowledgment is made of the assistance of the rail manufacturers, who made the special alloy steel rails and billets, the Oxweld Railroad Service Company, which flame-hardened the specimens used in the laboratory tests, and the railroad engineers who supplied the used alloy rails from their tracks.

Summary of Previous Work

In five previous reports printed in the Proceedings of the AREA the shelly rail problem has been explained. Two distinct types of shelling have been recognized which may be classified as follows:

1. The first type shown in Fig. 1 starts inside the rail head as horizontal cracks. These internal cracks may develop large transverse detail fractures before reaching the rail surface, which are as dangerous as transverse fissures.

2. The second type shown in Fig. 2 starts at or near the gage corner of the rail as head checks and flaking and gradually works into the rail head.

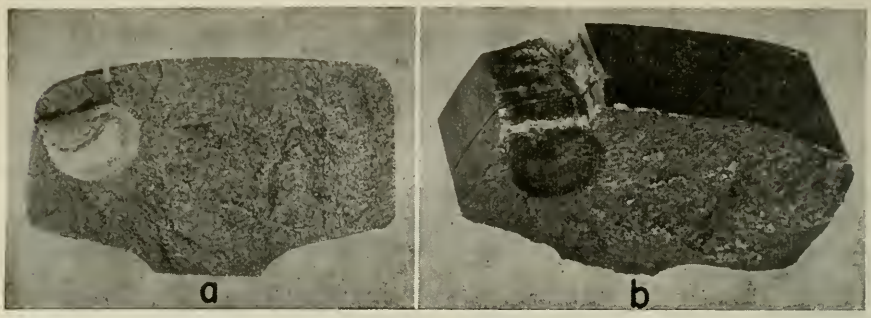


Fig. 1.—Detail Fracture from Shelly Spot, Type 1.
Lab. failed rail No. 497. Rolled in 1941.

(a) Small detail fracture which developed downward from a horizontal shelling crack ¼ in. below the gage corner of the rail.
(b) Same rail with horizontal shelling crack opened up.

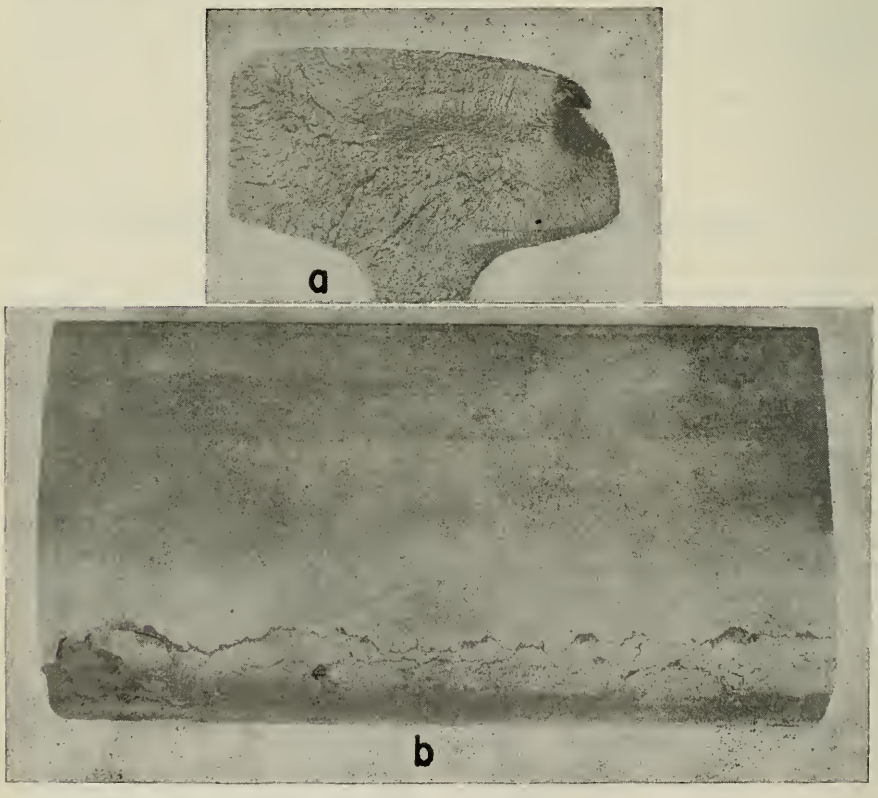
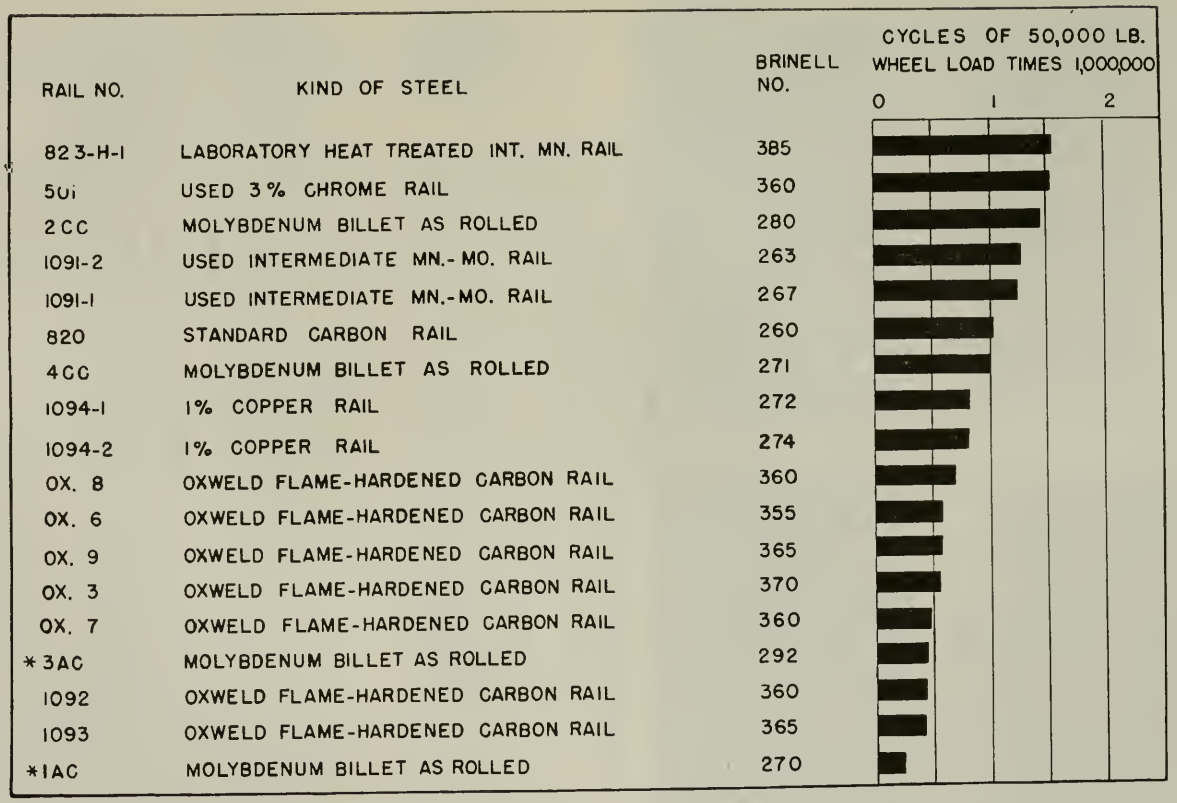


Fig. 2.—Detail Fracture from Shelly Spot, Type 2.
Lab. failed rail No. 511. Rolled in January 1938.

(a) Large detail fracture which developed inward from near the gage corner of the rail.
(b) Gage corner of rail lightly etched in acid. The longitudinal cracks may be head checks, which have progressed into the rail and caused surface shelling.


RAIL NO.
KIND OF STEEL
BRINELL NO.
CYCLES OF 50,000 LB. WHEEL LOAD TIMES 1,000,000
0
1
2
823-H-1 LABORATORY HEAT TREATED INT. MN. RAIL 385
50i USED 3% CHROME RAIL 360
2CC MOLYBDENUM BILLET AS ROLLED 280
1091-2 USED INTERMEDIATE MN.-MO. RAIL 263
1091-1 USED INTERMEDIATE MN.-MO. RAIL 267
820 STANDARD CARBON RAIL 260
4CC MOLYBDENUM BILLET AS ROLLED 271
1094-1 1% COPPER RAIL 272
1094-2 1% COPPER RAIL 274
OX. 8 OXWELD FLAME-HARDENED CARBON RAIL 360
OX. 6 OXWELD FLAME-HARDENED CARBON RAIL 355
OX. 9 OXWELD FLAME-HARDENED CARBON RAIL 365
OX. 3 OXWELD FLAME-HARDENED CARBON RAIL 370
OX. 7 OXWELD FLAME-HARDENED CARBON RAIL 360
*3AC MOLYBDENUM BILLET AS ROLLED 292
1092 OXWELD FLAME-HARDENED CARBON RAIL 360
1093 OXWELD FLAME-HARDENED CARBON RAIL 365
*1AC MOLYBDENUM BILLET AS ROLLED 270

* AIR COOLED BILLET CONTAINING SHATTER CRACKS

Fig. 3.—Rolling-Load Tests Made in Cradle Type Machine.

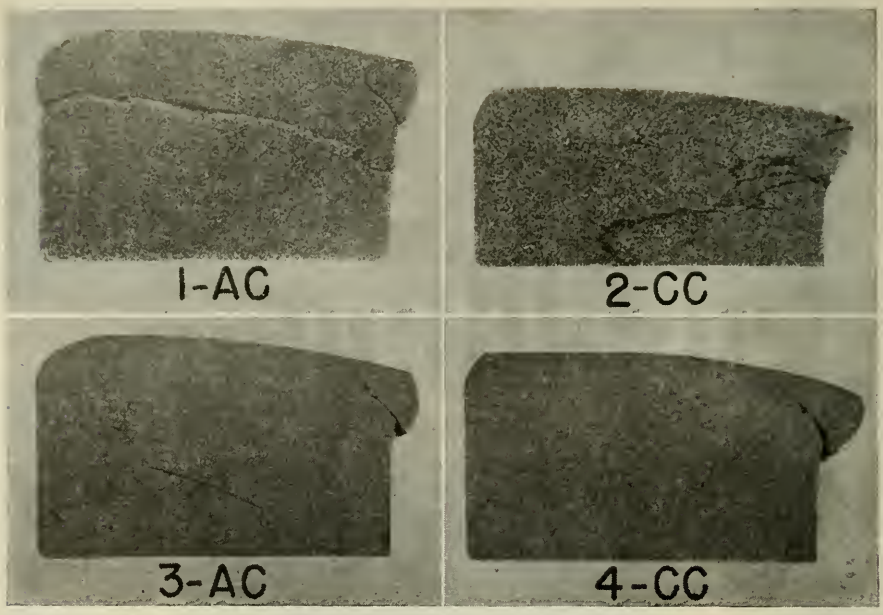


Fig. 4.—Shelling Cracks Developed in Cradle Type Rolling Machine. All specimens etched in 50 percent hot hydrochloric acid.

Specimen Number	*Kind of Specimen*	*Brinell Hardness*	*Cycles*
1. A.C.	Molybdenum billet air cooled	270	225,000
2. C.C.	Molybdenum billet control cooled	280	1,447,000
3. A.C.	Molybdenum billet air cooled	292	452,000
4. C.C.	Molybdenum billet control cooled	271	1,000,000

The first type become visible in the track by the formation of a dark spot on the gage corner of the rail. This dark spot forms after the horizontal shelling crack has broken through the side of the rail head and the tread metal has flowed to the gage corner, causing a low spot which is not kept bright by contact with car wheels. Even before the dark spot forms, the rail may develop a detail fracture from the internal horizontal shelling crack.

The second type of shelling which develops at the gage corner from the penetration of head checks and flaking cracks into the rail head is not always readily visible in the track. Sometimes the presence of grease and rust prevents the easy discovery of rather serious shelling. Detail fractures may also form early in the rails which develop this type of shelling.

Results of Recent Rolling-Load Tests

Table 1 lists the specimens tested in the cradle type rolling-load machine during the past year. It also gives the chemical analyses and Brinell hardness of each specimen. Physical properties are included for the specimens which could be tested. The bar

TABLE 1.—CHEMICAL ANALYSIS, PHYSICAL PROPERTIES AND ROLLING-LOAD TESTS OF RECENT TEST RAILS AND BILLETS

Specimen No.	Approx. Chemical Analysis Percent						Brinell Hardness	Yield Strength psi. 0.2% set	Tensile Strength psi.	Physical Tests		Charpy Value Unnotched Bar ft. lb.	Endurance Limit psi.	Cycles for Failure 50,000-lb. Wheel Load
	C	Mn	P	S	Si	Alloy				Elong. in 2 in. Percent	Reduc. of Area Percent			
Molybdenum Billets as Rolled														
						Mo.								
1–AC*	.63	.70	.010	.025	.24	.23	270	85,000	136,400	9.1	48.7	268	67,000	225,000
2–CC**	.63	.70	.010	.025	.24	.23	280	87,100	136,900	10.5	35.1	261	63,500	1,447,300
3–AC*	.63	.75	.010	.034	.24	.30	292	95,500	143,600	9.2	29.9	224	62,500	452,000
4–CC**	.63	.75	.010	.034	.24	.30	271	92,100	138,900	10.5	34.8	231	65,000	1,000,000
Oxweld Flame-Hardened Carbon Steel Rails														
1092	.73	.77	.020	.036	.20		360							450,000
1093	.73	.77	.020	.036	.20		365							427,000
Ox.3	.77	.90	.022	.031	.20		370							550,000
Ox.6	.77	.90	.022	.031	.20		355							564,000
Ox.7	.77	.90	.022	.031	.20		360							459,000
Ox.8	.77	.90	.022	.031	.20		360							696,000
Ox.9	.77	.90	.022	.031	.20		365							557,000
Used 3% Chrome Steel Rail														
						Cr.								
501	.31	.64	.020	.031	.37	3.19	360	129,900	173,200	8.5	38.1	300	70,000	1,532,400
Laboratory Heat-Treated Intermediate Mn Steel Rail														
823H 1	.59	1.36	.038	.029	.136		385	111,800	160,400	9.0	14.8	310		1,536,000
Used Int. Manganese–Molybdenum Rails														
						Mo.								
1091–1	.60	1.35	.03	.03	.12	.37	267	91,100	125,000	10.0	34.3	387	58,000	1,234,000
1091–2	.60	1.35	.03	.03	.12	.37	263							1,267,600
Standard Carbon Rail														
820	Standard Carbon Rail						260							1,043,500
One Percent Copper Rails														
						Cu.								
1094–1	.71	.80				1.11	272	75,000	135,900	7.5	16.6	73	62,000	822,000
1094–2	.71	.80				1.11	274							803,200

*Air cooled specimens contained shatter cracks.
**Controlled cooled specimens were free of shatter cracks.

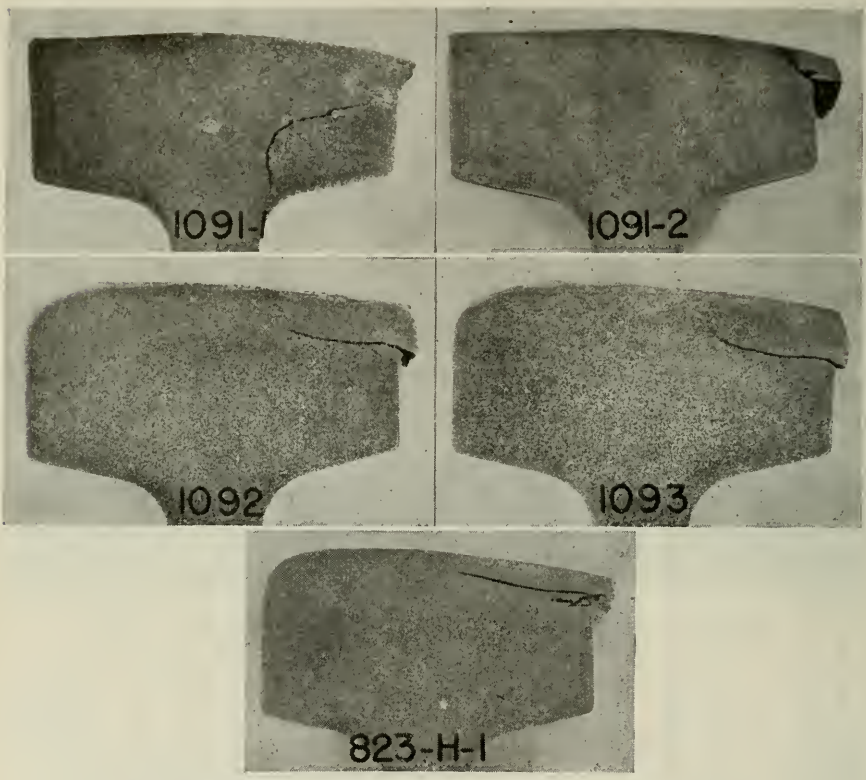


Fig. 5.—Shelling Cracks Developed in Cradle Type Rolling Machine. All specimens etched in 50 percent hot hydrochloric acid.

Specimen Number	*Kind of Specimen*	*Brinell Hardness*	*Cycles*
1091–1	Used Int. Mn–Mo–Rail	267	1,234,000
1091–2	Used Int. Mn–Mo–Rail	263	1,267,000
1092	Oxweld flame-hardened carbon rail	360	450,000
1093	Oxweld flame-hardened carbon rail	365	427,000
823–H–1	Lab. Heat-Treated Int. Mn Rail	385	1,536,000

graph of Fig. 3 gives relative test results for each rail. In the first group of four molybdenum billets listed in Table I the two control cooled specimens (numbers 2 and 4) gave results somewhat better than carbon steel rails. The air cooled specimens (numbers 1 and 3) contained shatter cracks and soon developed failures in the rolling-load machines.

The Oxweld flame-hardened specimens did not show as good results as standard carbon rails. The used 3 percent chromium steel rail had developed shelling in the tracks of the Norfolk & Western Railway and was sent to the university laboratory for examination. It will be noted that this chromium rail had an endurance limit of only 70,000 psi. as compared to an average of 98,000 psi. for previously reported 3 percent chromium rails. Microscopic examination has shown a considerable difference in the

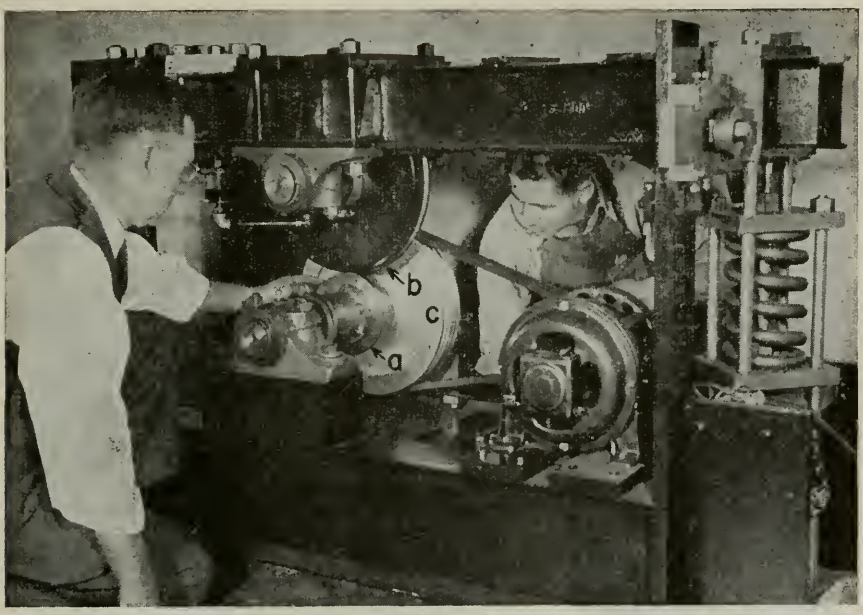


Fig. 6.—New Design Rolling Machine to Study Rail Shelling.

The specimen (a) is a disk 7 in. in diameter and 5/8 in. thick cut from the head web and base of a rail. This is rotated against a scale model car wheel (b) by the belt driven pulley (c). The model car wheel can be set to simulate rail service on curves.

grain structure of various chromium rails. The rolling-load tests of this specimen should not be compared to new 3 percent chromium rails because the two years' service in track had developed shelling on the gage side. These tests were made on the field side of the same rail. The test of laboratory heat-treated intermediate manganese rail gives results of a preliminary attempt at heat treating this steel. Other heat treatments should be tried on this steel before final judgment on its suitability for heat treatment. The used intermediate manganese–molybdenum rails had been in the tracks of the Delaware & Hudson Railroad a number of years and should not be compared to new rails. The one percent copper rails did not give as good results as standard carbon rails. The types of fractures developed in some specimens are shown in Figs. 4 and 5.

A New Type of Rolling Machine to Produce Shelling

At the suggestion of G. M. Magee, research engineer, AAR, a new type of rolling machine (Fig. 6) was designed by Proal Judson, a student assistant, and built in the laboratory by M. C. Moore, mechanician. The specimen (a) is a disc, 7 in. in diameter and 5/8 in. thick, cut vertically from the head, web and base of a rail. This specimen is mounted on a shaft driven by the pulley (c). The "scale model car wheel" (b) runs at a slight angle against the specimen simulating standard car wheels going around a curve. The top beam is pivoted for both vertical and lateral movement so the load and side thrust on the small car wheel are variable over a wide range. The advantage of this machine is the speed of operation, as it may be run up to 300 rpm. or more, and the fact that the flanged wheel sets at an angle with the specimen, thus simulating track conditions which produce shelling. Four specimens from one carbon steel rail have been

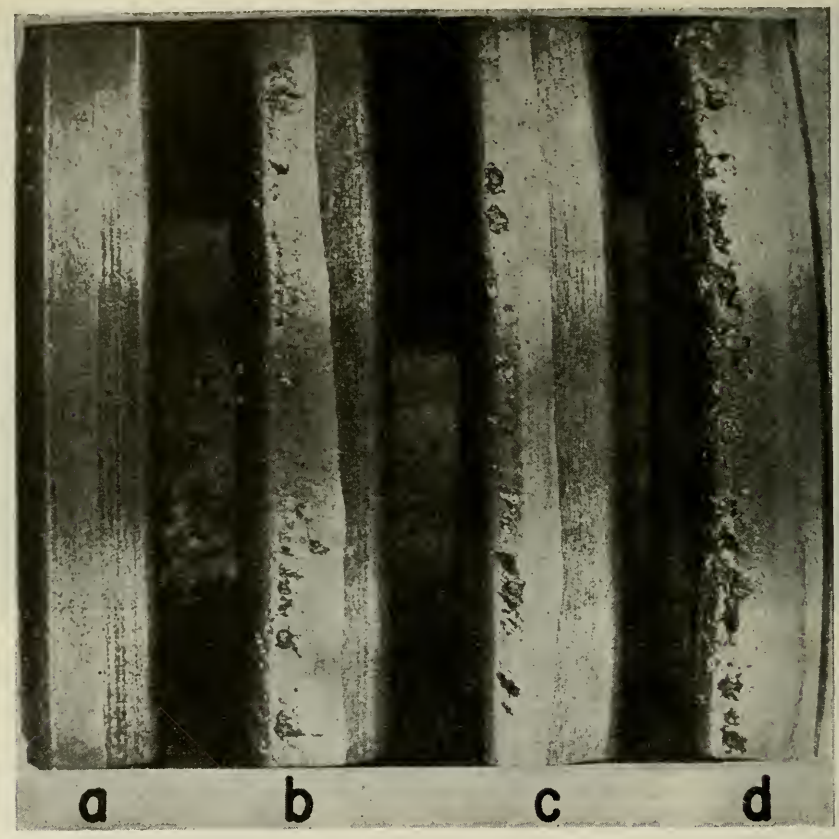


Fig. 7.—Flaking Developed on Four Round Specimens.

All specimens were run 2 million cycles. The wheel load varied as follows: a, 1000 lb.; b, 2000 lb.; c, 3000 lb.; d, 5000 lb.

Head checks developed on the gage corners at about 1 million cycles and these developed into flaking with further testing.

tested to 2 million cycles at wheel loads of 1000, 2000, 3000 and 5000 lb. Fig. 7 shows the condition of the treads of the discs after testing. All specimens developed head checks and flaking but the flaking was progressively worse at higher wheel loads. Discs from alloy and heat-treated rails will be tested in this machine.

Observations of Rails in Test Track Curves

In 1943 four curves on the Chesapeake & Ohio Railway were selected where shelling had previously developed. These were relaid with new carbon rails and have been examined by the writer each year since. Table 2 gives the results of observations made each year except 1945. It will be noted that the 5 and 6-deg. curves developed shelling at less traffic than the 3-deg. curves but as the traffic increased all curves have developed considerable shelling.

TABLE 2.—SUMMARY OF OBSERVATIONS ON TEN HIGH RAILS OF FOUR CURVES

Observations Made	*Curve No. 1* *Dillon, Va.* *Curvature 5° 10′* *Superelev. 3¼ in.* *Avg. Speed 40 mph.* *New Jan. 1943*	*Curve No. 2* *Buchanan, Va.* *Curvature 6°* *Superelev. 3¾ in.* *Avg. Speed 40 mph.* *New Jan. 1943*	*Curve No. 3* *Hinton, W. Va.* *Curvature 3° 36′* *Superelev. 3 in.* *Speed 60 mph. pass.* *35 mph. fgt.* *New April 1943*	*Curve No. 4* *Sewell, W. Va.* *Curvature 3° 30′* *Superelev. 3⅜ in.* *Speed 50 mph. pass.* *35 mph. fgt.* *New May 1943*
June 1943	Average Brinell 272 Very slight flow gage corner	Average Brinell 269 Very slight flow	Average Brinell 273 Some bead on gage side	Average Brinell 276 Good condition
June 1944	Traffic* 45.5 Average Brinell 296 Most rails flaking. 3 rails show dark shelly spots. Worst rail has 4 dark spots.	Traffic 45.4 Average Brinell 294 Most rails flaking. 3 rails starting to develop small dark shelly spots.	Traffic 29.9 Average Brinell 305 Practically all rails show some flaking but no dark shelly spots.	Traffic 14.4 Average Brinell 302 Rails in good condition.
June 1946	Traffic 114 Average Brinell 310 5 turned rails still in track now show flaking on gage corners. 3 rails not turned have heavy shelling. 2 show medium flaking.	Traffic 114 Average Brinell 300 8 rails have 10 to 25 dark shelly spots. 1 rail 7 shells. 1 rail 3 shells.	Traffic 86.2 Average Brinell 315 2 rails have developed 1 dark shelly spot each. 7 rails show flaking. 1 rail clear.	Traffic 39.5 Average Brinell 314 1 rail has a dark shelly spot. 6 rails show flaking. 3 rails clear.
June 1947	Traffic 150 7 rails have been turned. 1 shows 1 shell, 6 show flaking on new gage corners. 3 rails not turned—one shows heavy shelling, 2 not on sharp curve are flaking.	Traffic 150 8 rails—heavy shelling 1 rail—7 shells 1 rail—4 shells	Traffic 116 1 rail—2 shells 1 rail—1 shell 7 rails—flaking 1 rail—not on sharp curve—clear	Traffic 53 1 rail—4 shells 4 rails—2 shells 1 rail—1 shell 2 rails—flaking 2 rails—clear

*Traffic reported in million gross tons.

Summary of All Shelly Rail Tests at the University of Illinois

Previous reports have given the results of laboratory physical tests and rolling load tests on 25 rails. This report gives new data on 18 more rails. The rolling-load test is considered to give a comparative indication of how long the rails would last in railroad service.

Standard carbon steel rails have averaged 811,500 cycles in the cradle rolling machine, 3 percent chromium steel rails have averaged 3,136,000 cycles and laboratory heat-treated carbon steel rails averaged 4,565,000 cycles. Medium alloy steel rails heat treated averaged 2,742,000 cycles. From the results of these tests it can be predicted that either heat-treated carbon steel rails or some alloy steel rails can be expected to give two or more times the service life of standard carbon steel rails. The writer believes that careful consideration should be given as to the possibility of developing a commercial practice of heat treating carbon steel rails as an economical solution of the shelly rail problem. However, it also seems advisable to continue testing alloy steels both as-rolled and heat treated, and special treatments, such as the flame-hardening of the rail treads.

Conclusions

1. Only one kind of alloy rail, the 3 percent chromium has given high test results in the as-rolled condition.

2. Either carbon steel rails or certain low-alloy rails have given high test results in the heat treated condition.

Appendix 11–c

Progress Report on Shelly Rail Studies

to

The Joint Contact Committee on Rails of Association of American Railroads and American Iron and Steel Institute

from

Battelle Memorial Institute

By H. A. Blank and G. K. Manning

Introduction

A study of shelly rails was started at Battelle Memorial Institute on June 1, 1946, under the joint sponsorship of the Association of American Railroads and the American Iron and Steel Institute. The purpose of the study was to correlate, if possible, some mechanical property or some metallographic characteristics of rail steel with shelling. Since the study was initiated, 7 different railroads sent 69 shelly rail specimens to Battelle for examination. Through the close cooperation of the Norfolk & Western Railway, three pairs of carbon rails (each of which included one shelled rail, and one satisfactory rail) and three chromium rails were made available for examination. The acquisition of these rails was fortunate because it offered a chance to compare the mechanical properties and microstructure of rails which had shelled with rails which had not shelled although both had been subjected to the same service conditions.

It has been the opinion of many that shelling cracks start internally and progress radially from these centers. However, examination of shelled rail specimens indicates that shelling also starts at the surface and progresses inwardly. Therefore, much of the metallographic work was directed toward determining (1) the origin of the shelly cracks, and (2) searching for abnormal defects in the steel.

Spectrographic analysis was also made of 4 rails to determine the amount of 13 different residual elements present in each. These analyses permitted another comparison between rails which had shelled and rails which were, at least, somwhat more resistant to shelling.

Experimental Work

The examination of shelly rail specimens revealed (1) fractures having a vertical and a horizontal component, and (2) fractures having only a horizontal component. When defective rails are removed from service, those having a vertical component are classified as "detail fractures from shelling." Some of these "detail fractures," when broken, have a shiny surface while others are oxidized. In the past, it was concluded that a bright fracture had not reached the surface. However, two specimens, one of which is shown in Fig. 1, had shiny fractures that were connected to the surface. The vertical component of the rail in Fig. 1 was connected to an oxidized horizontal component. However, a deep etch of the cross section of these two rails revealed no abnormally large inclusions. These two rails may be isolated cases, but it is apparent that a bright surface is not conclusive evidence that the defect was entirely internal and not connected with the rail surface.

Rails that contained detail fractures were opened for examination to determine the nature of the horizontal component. Usually, the horizontal component connected to shiny detail fractures ranged in lengths from only ¼ to ½ in. and then, in most cases, turned upward towards the rail head. Fig. 2 is a photograph of a typical example. Note that the horizontal component is very short and merely acts as a shelf between two vertical components. Cross sections of some 16 rails having shiny detail fractures were ground and deep-etched in a hot solution of 38 percent hydrochloric acid and 12 percent sulfuric acid in water to detect any defect in the steel. Only one specimen contained an abnormally large inclusion. This inclusion, which was a complex oxide containing iron, manganese, and silicon, probably influenced the formation of the fracture. No abnormal defects in the steel were detected in the other 15 rail specimens although, of course, relatively small oxide and sulfide inclusions similar to those found in other areas were present in the vicinity of all the cracks.

The second type of shelled defects, those having only a horizontal component, are usually classified as shelly fractures. Shelly rail specimens were examined to determine if any concentric growth rings could be found on the shelled area. The presence of these rings would be evidence of subsurface origin. However, no complete concentric rings were detected but partial concentric growth rings were found on a few of the shelly surfaces. Growth lines that are perpendicular to the axis of the rail were found on the surface of most of the shelly areas. The presence of these lines is interpreted as being an indication of surface origin. Figs. 3 and 4 are photographs which show the presence of these perpendicular growth lines. A close observation of Fig. 3 reveals the formation of a thin lip of metal on the gage side of the rail. There is evidence that shelling is, at times, associated with this lip. It appears that the formation of this lip precedes the formation of a shelly crack immediately under the lip. If this is true, then a steel which work hardens very quickly when put in service, so that such a lip does not form, may show much greater resistance to shelling. There is some evidence that additions of

Fig. 1.—Photograph at 2 × of a Chesapeake & Ohio Rail Specimen. In this case, the unoxidized vertical component did not extend to the surface, but it was connected to an oxidized horizontal component.

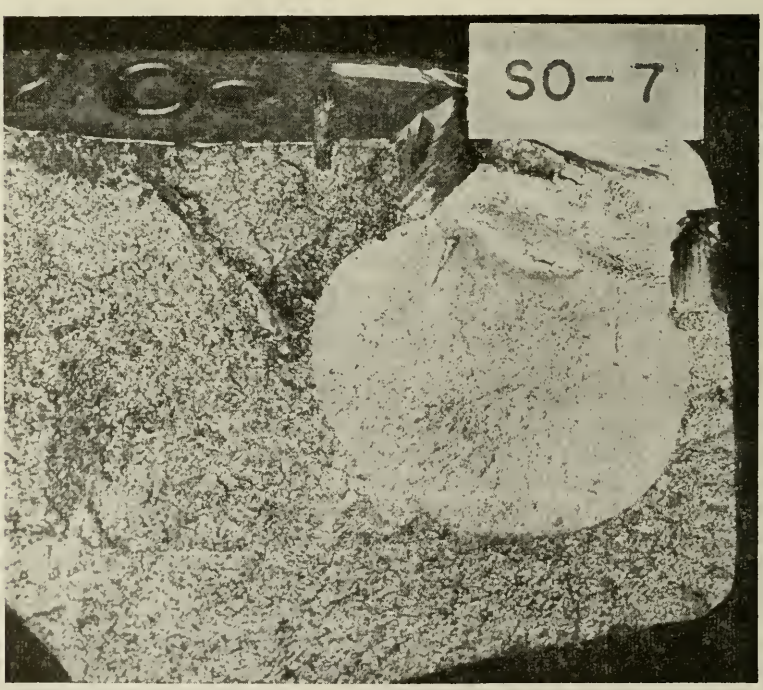


Fig. 2.—Photograph at 2× of the Defect in Southern Railroad Specimen No. 7.

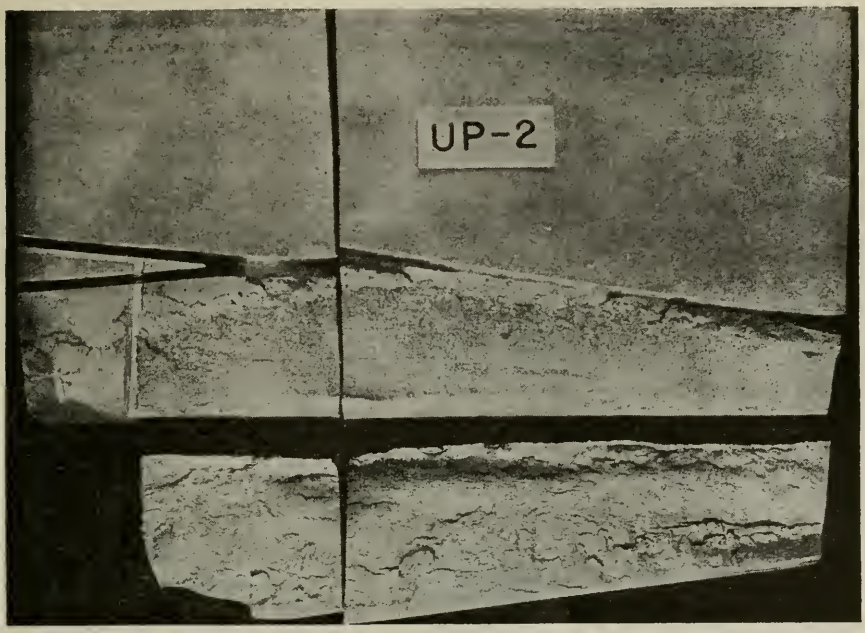


Fig. 3.—Photograph of a Rail from the Union Pacific (No. U.P.2). Here, the growth lines are perpendicular to the rail length. The large cracks in the top part of the rail are probably caused by the excessive pounding after this part was separated from the body of the rail.

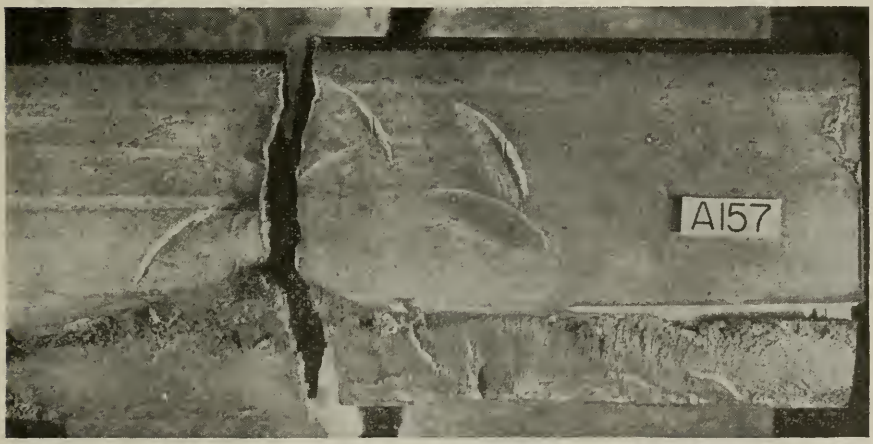


Fig. 4.—Photograph of the Shelled area of a Chesapeake & Ohio Rail Specimen. Note the presence of the growth lines and the absence of any vertical component.

aluminum and nitrogen to low-carbon steels increase the rate of work hardening. It was not known whether this effect would also be apparent in high-carbon steels. Consequently, two experimental ingots of rail steel composition were made, and aluminum and calcium cyanamide were added to one of the ingots. Forged bars from each ingot were cold rolled 0, 2, 6, and 15 percent so that the final thickness was approximately 0.800 in. Standard 0.505-in. tensile specimens and unnotched Charpy bars were machined from these cold rolled bars. The results from the mechanical tests of these bars showed no appreciable difference between the work-hardening characteristics of the two ingots. The yield point, tensile strength, and Brinell hardness value of both ingots increased at the same rate with increasing amounts of cold work.

The effect of cold work was determined on the three pairs of carbon rails and the three chromium rails that were taken from the Norfolk & Western tracks. A description of these specimens is listed in Table 1. Carbon rails, Nos. 1 through 6, were removed from track in pairs. Rail Nos. 1 and 2 were from the same heat and were taken from adjacent rails laid at the same time. Similarly, Nos. 3 and 4, and Nos. 5 and 6 were from the same heat and were taken from adjacent rails laid at the same time. In each pair, the odd numbered rail shelled readily, and the even numbered rails exhibited either no shelling or only a minor degree of shelling. Rail Nos. 7 through 9 are 3 percent chromium rails. Two of these rails (N. W. 7 and 8) shelled while the other rail (N. W. 9) did not shell. Prior to cold working, four specimens, to be rolled with the specimen axis parallel to the direction of hot rolling, were cut from the lower portion of each rail head. Four other specimens, to be rolled with the specimen axis perpendicular to the direction of hot rolling, were cut from the web of each rail. The original thickness was varied in such a way that, after cold rolling, 0, 2, 6, and 15 percent, the final thickness was 0.5 in. Standard 0.505-in. tensile and unnotched Charpy impact bars were made from these cold-rolled bars. The yield point,* tensile strength, percent elongation, percent reduction of area, Brinell hardness value, and unnotched Charpy impact values were determined on each specimen.

The curves in Figs. 5 through 10 show the results obtained from the carbon rail. Results for the chromium rails have not been reproduced since they were similar in character to those obtained for the carbon rails. These curves show that cold rolling gave no convincing evidence that the satisfactory rails possessed different strain-hardening characteristics than the rails which shelled. Cold working increased the yield point, tensile strength, and Brinell hardness values of both the shelled and satisfactory rails to approximately the same degree. The percent elongation, the percent reduction of area, and the unnotched Charpy impact values were decreased in both the shelled and satisfactory rails. Here too, there was no conspicuous difference in the amount of decrease between the shelled and satisfactory specimens.

The carbon rails which did not shell (N. W. 2, 4, and 6) had initial yield points about 10,000 psi. and tensile strengths about 15,000 psi. greater than those rails which shelled (N. W. 1, 3, and 5). This same condition apparently existed in the chromium rails. However, the three chromium rails had much higher tensile strength values (approximately 45,000 psi. higher) than the three satisfactory carbon rails. There is no doubt that a relationship does exist between tensile strength (or hardness) and shelling, the higher the strength the greater the resistance to shelling. However, since some of the chromium rail, with its relatively high strength, shelled after having carried less tonnage than carried by some carbon rails, it appears that the relationship is not a

* The yield points were determined by the dividers method. Although this method was satisfactory for the carbon rails, it was unsatisfactory for the cromium rails. As a result, the yield point data for the chromium rails were not obtained.

(text continued on page 458)

TABLE 1.—HISTORY OF RAIL SPECIMENS REMOVED FROM NORFOLK & WESTERN TRACK

Specimen Number	*Description of the Specimen*	*Manufacturer*	*Heat Number*	*Curve*	*Date Laid*	*Date Removed*	*Traffic Carried Million Tons*
N.W.1	Shelled	Carnegie	206209–E–20	5°46″	May 1937	July 1946	152
N.W.2	Adjoining No. 1 rail but did not shell	"	206209–C–16	5°46″	May 1937	"	152
N.W.3	Shelled	"	06E572–E–1	6°	Feb. 1945	"	57
N.W.4	Adjoining No. 3 rail but did not shell	"	06E572–D–4	6°	Feb. 1945	"	57
N.W.5	Shelled	"	208223–O–30	6°	June 1942	"	199
N.W.6	Adjoining No. 5 rail—badly flaked but did not shell	"	208223–B–32	6°	June 1942	"	199
N.W.7	3% chromium rail—shelled	"	940564–D–5	7°	April 1945	June 1946	49
N.W.8	3% chromium rail—shelled	"	940564–B–7	7°	April 1945	"	49
N.W.9	3% chromium rail—not shelled	"	940328–A–19	6°	August 1944	July 1946	83

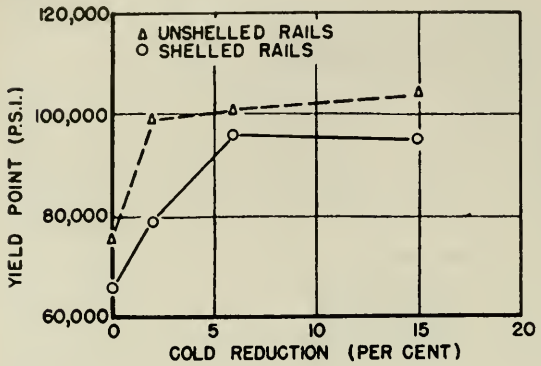


Fig. 5.—Curves Showing the Effect of Cold Work on the Yield Point of Rails. The Points of Each Curve are the Average of the Longitudinal and Transverse Values of 3 Carbon Rails.

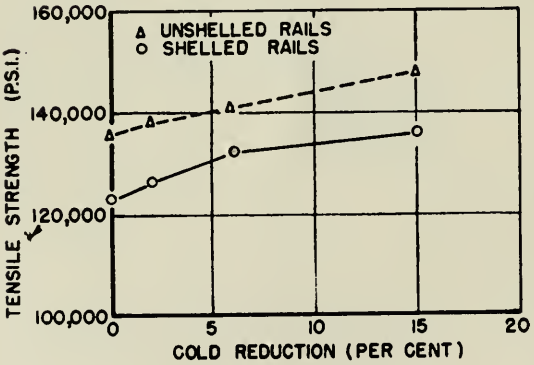


Fig. 6.—Curves Showing the Effect of Cold Work on the Tensile Strength of Rails. The Points of Each Curve are the Average of the Longitudinal and Transverse Values of 3 Carbon Rails.

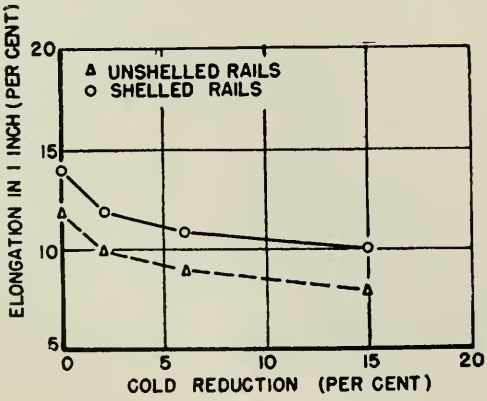


Fig. 7.—Curves Showing the Effect of Cold Work on the Percent Elongation of Rails. The Points of Each Curve are the Average of the Longitudinal and Transverse Values of 3 Carbon Rails.

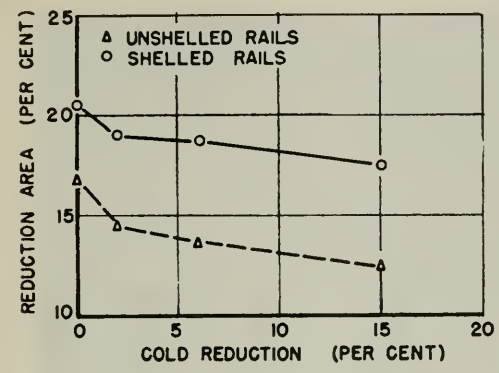


Fig. 8.—Curves Showing the Effect of Cold Work on the Percent Reduction of Area of Rails. The Points of Each Curve are the Average of the Longitudinal and Transverse Values of 3 Carbon Rails.

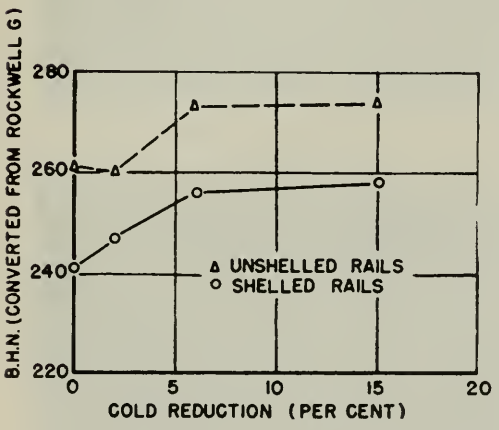


Fig. 9.—Curves Showing the Effect of Cold Work on the Brinell Hardness Number of Rails. The Points of Each Curve are the Average of the Longitudinal and Transverse Values of 3 Carbon Rails.

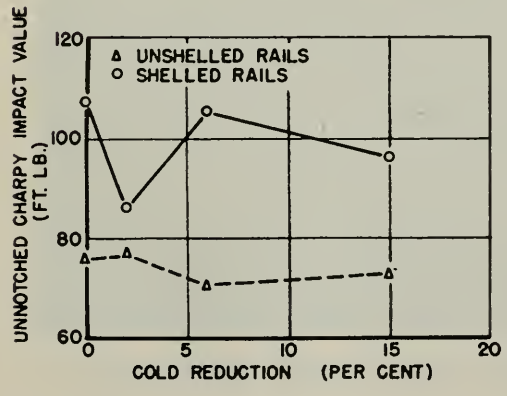


Fig. 10.—Curves Showing the Effect of Cold Work on the Unnotched Charpy Impact Value of Rails. The Points of Each Curve are the Average of the Longitudinal and Transverse Values of 3 Carbon Rails.

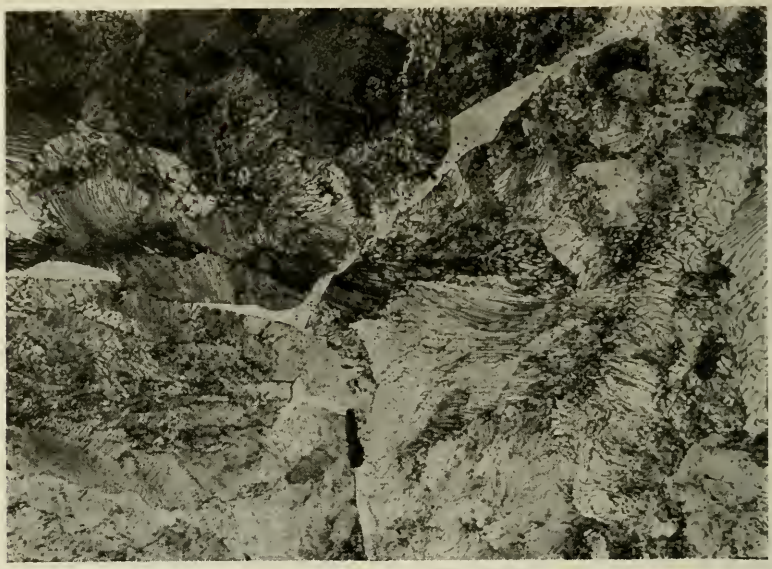


Fig. 11.—Photomicrograph at 500× of Norfolk & Western Rail No. 1. Free ferrite was scattered throughout the grain boundaries. This rail shelled.

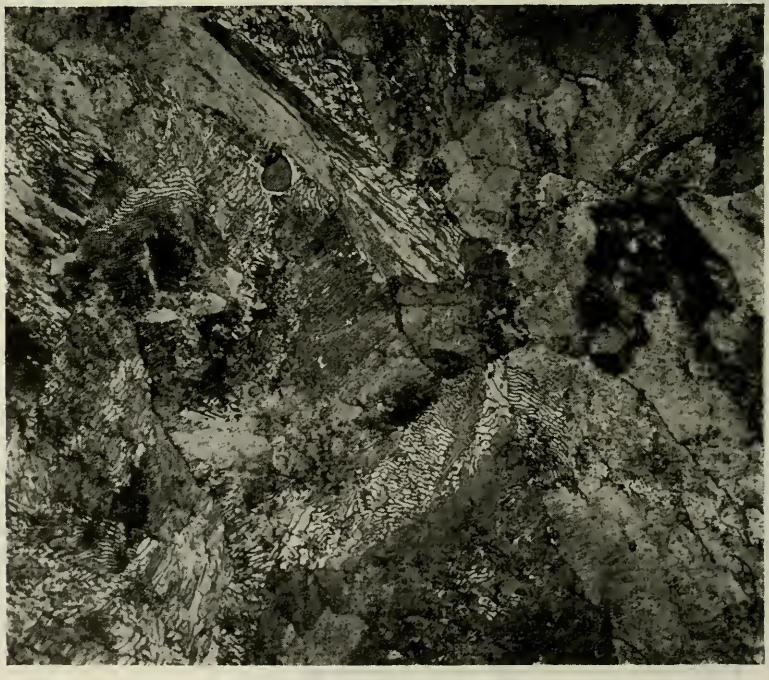


Fig. 12.—Photomicrograph at 500× of Norfolk & Western Rail No. 2. No ferrite was deposited in the grain boundaries. This rail did not shell.

Fig. 13.—Photomicrograph at 500× of Norfolk & Western Rail No. 3. Free ferrite was scattered throughout the grain boundaries. This rail shelled.

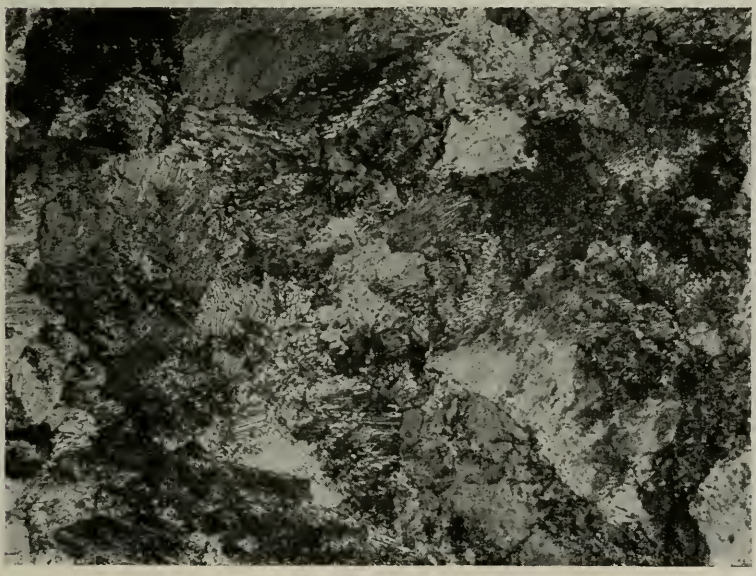


Fig. 14.—Photomicrograph at 500× of Norfolk & Western Rail No. 4. No free ferrite was deposited in the grain boundaries. This rail did not shell.

Fig. 15.—Photomicrograph at 500× of Norfolk & Western Rail No. 5. No free ferrite is in the grain boundaries. This rail shelled.

Fig. 16.—Photomicrograph at 500× of Norfolk & Western Rail No. 6. No free ferrite was deposited in the grain boundaries. This rail did not shell.

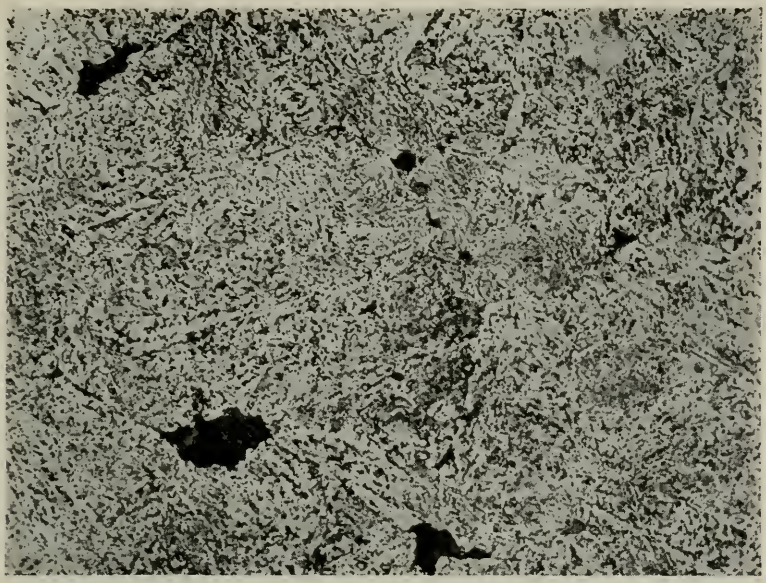


Fig. 17.—Photomicrograph at 500× of Norfolk & Western Rail No. 7. This is a 3 percent chromium rail. The dark constituent is fine troostite imbedded in a matrix of coarse bainite. This rail shelled.

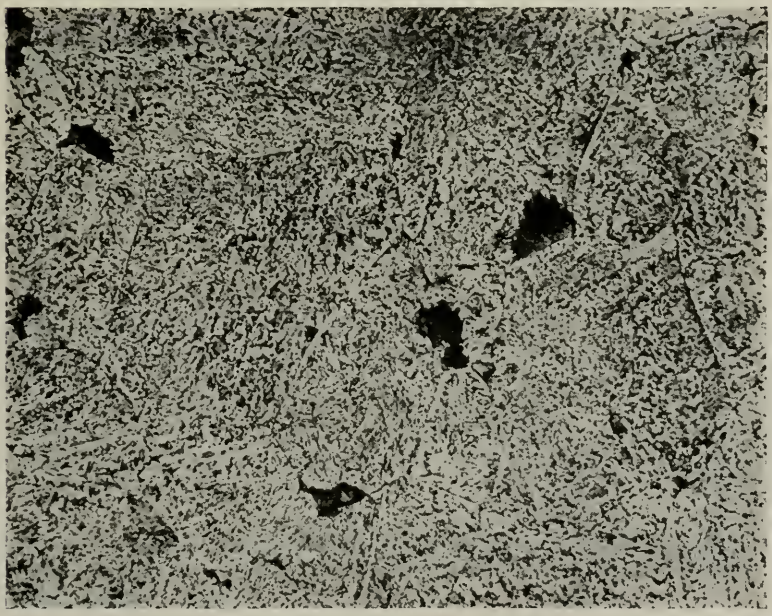


Fig. 18.—Photomicrograph at 500× of Norfolk & Western Rail No. 8. This is a 3 percent chromium rail. It also has traces of fine pearlite imbedded in a matrix of coarse bainite. This rail shelled.

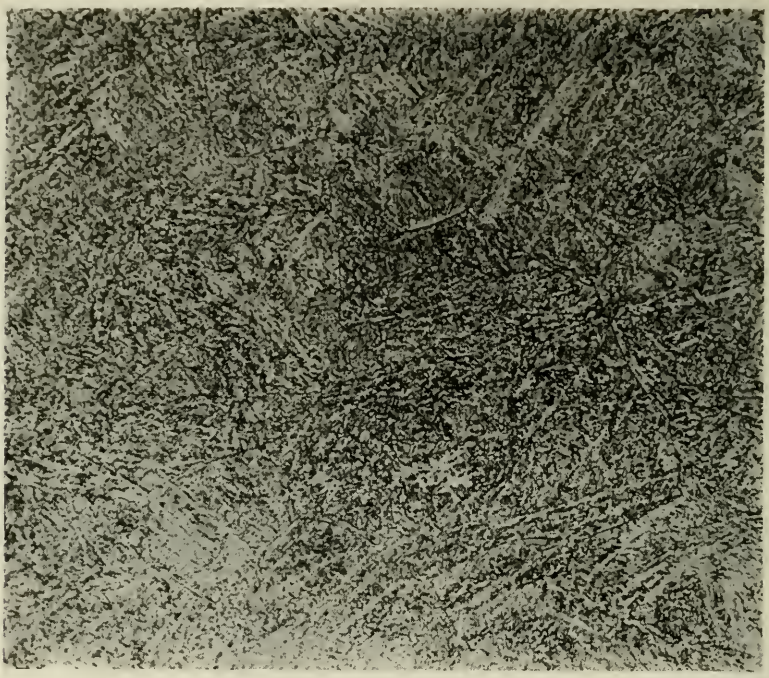


Fig. 19.—Photomicrograph at 500× of Norfolk & Western Rail No. 9. This is a 3 percent chromium rail. Note the absence of the fine pearlite and the finer bainitic structure than those shown in Figs. 33 and 34. This rail did not shell.

(text continued from page 450)

simple one. It is suspected that rails of similar microstructure may exhibit a resistance to shelling that is simply related to their strength or hardness. It may also be that shelling is simply related to yield strength and accurate yield strength data will be obtained on future specimens in an effort to determine this.

Samples were cut from the gage corner of each Norfolk & Western rail specimen, and photomicrographs at 500× were taken at a point below the work-hardened metal. Figs. 11 through 19 show these photomicrographs. Examination of Figs. 11 through 16 shows that the three satisfactory carbon rails (N. W. 2, 4, and 6) have a finer pearlitic structure than the three shelled carbon rails (N. W. 1, 3, and 5). Free ferrite, a weak constituent, is scattered throughout the grain boundaries of two of the shelled rails. A similar condition existed in the chromium rails (Figs. 17 through 19). The satisfactory chromium rail (N. W. 9) had a finer bainitic structure, with no fine pearlite present, than the two shelled chromium rails (N. W. 7 and 8).

A carbon analysis was made at the O and M positions (ASTM specifications) of each carbon rail. Table 2 contains the results of this analysis and shows that the shelled rails have less carbon than the satisfactory rails. This explains the presence of the free ferrite.

Samples were taken from 4 different rail specimens for a spectrographic analysis to determine the amount of 13 different residual elements present in each. The rails were

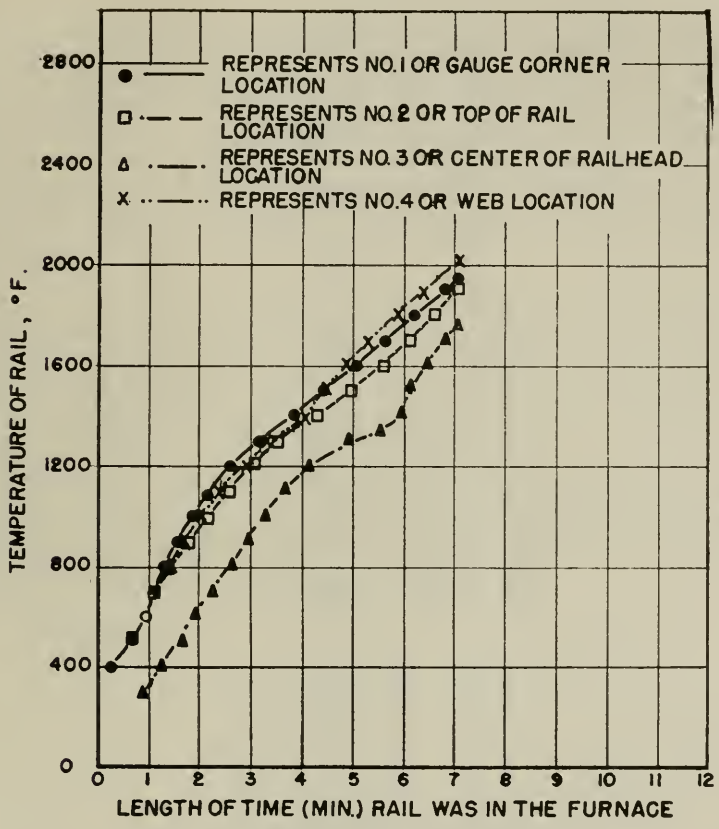

REPRESENTS NO. 1 OR GAUGE CORNER LOCATION
REPRESENTS NO. 2 OR TOP OF RAIL LOCATION
REPRESENTS NO. 3 OR CENTER OF RAILHEAD LOCATION
REPRESENTS NO. 4 OR WEB LOCATION
TEMPERATURE OF RAIL, °F.
2800
2400
2000
1600
1200
800
400
0
0 1 2 3 4 5 6 7 8 9 10 11 12
LENGTH OF TIME (MIN.) RAIL WAS IN THE FURNACE

Fig. 20.—Heating Curves Obtained on 131-lb. RE Rail. The Gas was Turned on Continuously while the Temperature Measurements Were Made.

TABLE 2.—PERCENT CARBON OF NORFOLK & WESTERN CARBON RAIL SPECIMENS

Rail Number	*Percent Carbon*		
	O Location at Gage Corner	*M Location*	*O Location at Outside Corner*
N. W. 1*	0.71	0.63	0.72
N. W. 2	0.80	0.77	0.78
N. W. 3*	0.75	0.64	0.76
N. W. 4	0.81	0.77	0.79
N. W. 5*	0.83	0.78	0.83
N. W. 6	0.87	0.90	0.86

*These rails shelled.

TABLE 3.—AMOUNT OF RESIDUAL ELEMENTS IN SHELLED AND UNSHELLED RAILS**

Rail Number	Traffic Carried in Million Tons	Percent of Element Present												
		Sb	Cr	Ni	Mo	Cu	Al	V	B	Sn	Pb	As	Ti	Zn
N.W.6	199	N.D.	0.03	0.02	0.005	0.04	0.02	0.005	0.0005	0.01	N.D.	N.D.	0.005	N.D.
A–158*	205	N.D.	0.02	0.03	0.005	0.03	0.02	N.D.	N.D.	0.01	0.01	N.D.	N.D.	N.D.
N.W.9	83	N.D.	3–5	0.05	0.01	0.04	0.02	N.D.	N.D.	0.01	0.01	N.D.	N.D.	N.D.
N.W.8*	49	N.D.	3–5	0.04	0.01	0.04	0.02	N.D.	N.D.	0.01	0.02	N.D.	N.D.	N.D.

* These rails shelled.
** Determined spectrographically.
N.D. Indicates not detected.

selected in pairs. Rails N. W. 6 and A-158 constituted one pair because they were both carbon rails and had essentially the same composition, carried the same tonnage, and came from different heats, yet A-158 shelled and N. W. 6 did not shell. Rails N. W. 8 and 9, making the other pair, were both 3 percent chromium rails and came from different heats. Rail N. W. 9 had not shelled when removed from service although it had carried twice as much tonnage as N. W. 8. If this analysis had shown an appreciable difference in residual-alloy content between the shelled and satisfactory rails, one might suppose that difference to be connected with shelling. However, each rail contained practically the same amount of each element. The results of this analysis are shown in Table 3.

The evidence that both hardness and microstructure affect a rail's resistance to shelling appeared to be worthy of further consideration. One method of simultaneously achieving both an increase in the hardness and greater homogeneity in the microstructure is by heat treatment of the rail. With this thought in mind, the heating and cooling rates of 131-lb. RE rail were obtained for a specific set of conditions. Such data would be useful in attempting to design commercial equipment for the heat treatment of rail.

Chromel-alumel thermocouples were attached to 5 different locations midway between the ends of a 13-in. section of a 131-lb. RE rail. Five-sixteenth-inch holes were drilled into the rail. The thermocouple beads were placed in these holes and sealed with a high-temperature cement to insure contact between the thermocouple bead and the rail. The number and location of each thermocouple are shown below:

Thermocouple Number	*Location of the Thermocouple Bead*
1	5/16 in. below the gage corner
2	5/16 in. below the top of the rail and at the center of the rail head
3	7/8 in. below the top of the rail and in the center of the rail head
4	Half way through the web and approximately 2½ in. below the top surface of the rail head
5	1/8 in. below the surface of the flange

Thermocouple No. 5 became detached from the rail during heating and no readings were obtained at this location. For this experiment, a gas-fired pot furnace was used. The gas was turned on, and after the furnace walls were approximately 2700 deg. F., the rail specimen was lowered into the furnace. Temperature readings were taken on each location approximately 3 sec. apart. The heating curves obtained are shown in Fig. 20. One notes on the curves that the No. 3 location was heated to 1750 deg. 7 min. after the rail was placed in the furnace. The curves also show that there was a temperature gradient of from 150 deg. F. and 250 deg. F. between the No. 3 location (center of rail head) and the other locations. However, a furnace design which permits an equalization zone will eliminate this gradient. The experiment described below illustrates this point. In this experiment, the rail section was again placed in the preheated furnace and the gas was turned on. This time the gas was turned off when the No. 1 location (5/16 in. below the gage corner) reached 1600 deg. F. After the gas was turned off, the rail was kept in the furnace until the temperature of the No. 3 location (7/8 in. below the top of the rail and in the center of the rail head) became 1760 deg. F. The resulting heating curves are shown in Fig. 21. After a total time of about 9 min., the rail was at a temperature of 1700 deg. F. and exhibited a gradient between surface and center of less than 25 deg. F.

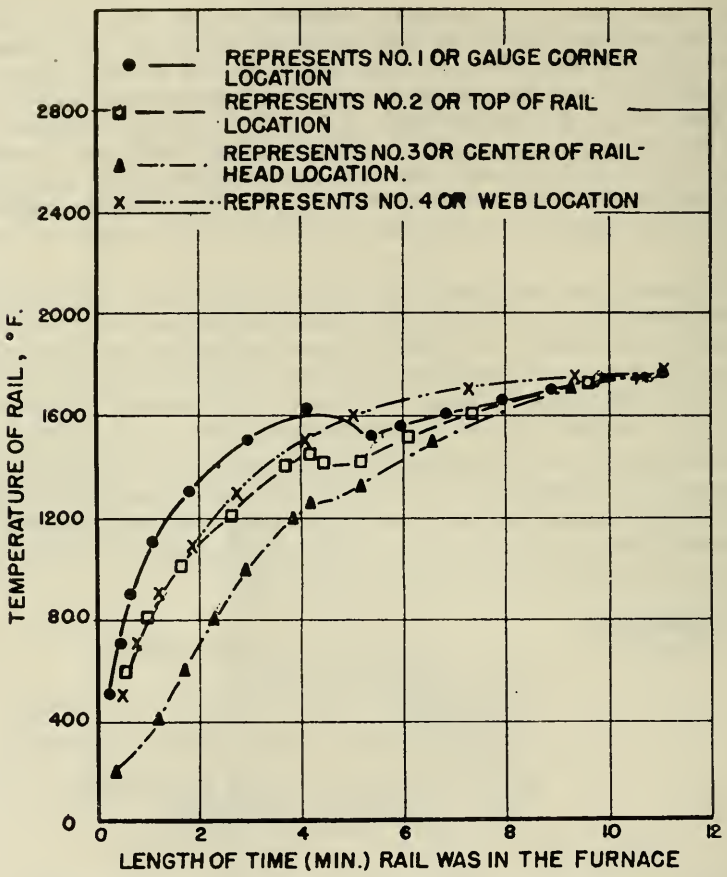


Fig. 21.—Heating Curves Obtained on a 131-lb. Rail. The Gas was Turned Off 4.08 Min. after the Rail was Placed in the Furnace.

An attempt to record cooling data at the Nos. 1, 2, and 3 locations was made. However, the No. 1 and 2 thermocouples became detached from the rail when the specimen was placed in the quenching tanks and, as a result, data from only one location (No. 3) were obtained. The rail specimen was heated to 1650 deg. F. and quenched in an agitated water bath. Owing to a fault in the quenching apparatus, the first temperature reading was delayed approximately 10 sec. After the initial reading, temperature measurements were made approximately every 3 sec. Fig. 22 contains the cooling curve obtained from this experiment. The curves show that the center of the rail head can be cooled from 1650 deg. F. to 500 deg. F. in about 35 sec. By comparing these data with available data on quenched rounds, it is apparent that the rail head acts similarly to a 1¾-in. diameter round. These experiments did not show the maximum heating and cooling rates obtainable on a 131-lb. RE rail, but they did serve the purpose of showing that rail can be heated to a reasonably uniform temperature and cooled from that temperature in practical time periods.

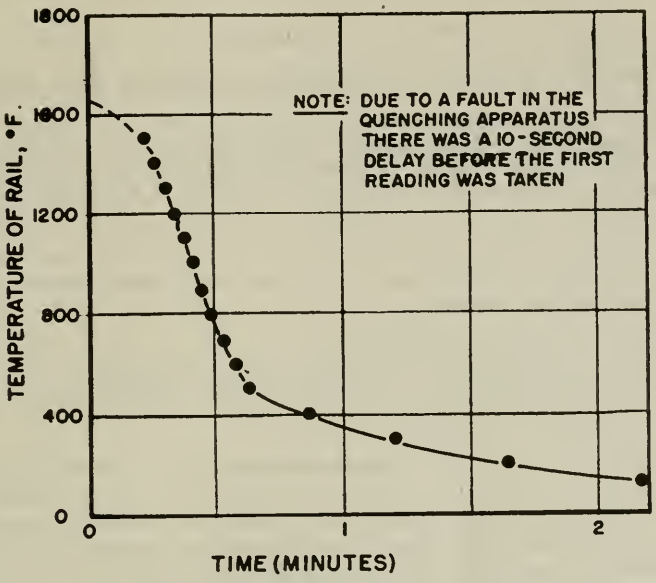


Fig. 22.—Cooling Curves Obtained by Measuring the Temperature at the No. 3 Location on the 131-lb. Rail. The 13-in. Piece of Rail was Heated Uniformly to 1650 deg. F. and Quenched in an Agitated Water Bath.

Field Test

On May 18, 1947, new test rails for shelling studies were installed in curve No. 7 on the middle division of the Pennsylvania Railroad. This site was selected by the Pennsylvania because shelling has developed in a relatively short time on this curve. The purpose of this test is to determine what effect the metal lip that forms on the gage side of the rail has on shelling. This is being done by grinding the lip from the gage corner of alternate rails. For this test, 22 rails were chosen for observation. During the first two months of the test, the metal lip had to be ground off every two weeks. Now, the rails have work hardened sufficiently so that grinding is necessary only once a month. To date, no shelling has developed on any of the rails. However, early stages of flaking were found on 8 of the 11 ground and 7 of the 11 unground rails. This condition was found to be in a more advanced stage on the first 6 rails of the receiving end of the curve.

Report on Assignment 12

Investigate Recent Developments Affecting Rail Design

C. J. Code (chairman, subcommittee), J. E. Armstrong, S. E. Armstrong, W. C. Barnes, C. B. Bronson, W. J. Burton, H. R. Clarke, L. S. Crane, P. O. Ferris, G. F. Hand, F. S. Hewes, S. R. Hursh, G. M. Magee, Ray McBrian, R. J. Middleton, C. E. Morgan, R. A. Morrison, L. T. Nuckols, W. C. Perkins, G. A. Phillips, F. S. Schwinn, G. L. Smith.

A year ago as a result of work done under the sponsorship of this subcommittee, three new rail sections, the 115-lb., 132-lb., and 133-lb., were adopted, along with corresponding joint bar sections.

Supplementary reports were submitted on

(a) Stress measurements on the Norfolk & Western Railway, 1945.
(b) Stress measurements on the Detroit, Toledo & Ironton Railroad, June 1946.
(c) Fatigue tests of rail webs.

The program of work for 1947 included field measurement of web stress in the new sections, laboratory and field investigation of stresses in the rail web within joint bar limits, and continuation of the work at the University of Illinois in studying fatigue strength of rail web steel, particularly as it is affected by corrosion.

The field measurement of web stresses in the new sections has been postponed, to give preference to field work in connection with stresses in joint bar limits.

It was thought advisable to push this work to an early conclusion in order to permit the use of the new recommended bolt spacing for 1948 rail orders.

Laboratory and service tests have been made of stresses within joint bar limits, and Appendix 12–a submitted herewith presents the results of this work, which was carried out by the research staff. As a result of these studies, recommendation has been made for the adoption of revised bolt hole spacing for 24-in. and 36-in. joints.

Fatigue tests of rail web steel have been continued at the University of Illinois, and Appendix 12–b submitted herewith covers the results of these tests, the work consisting primarily of a test of certain corrosion resistive coatings.

The program for work under the sponsorship of this subcommittee for the ensuing year includes (a) continuation of the study of fatigue of rail web steel, (b) field measurement of web stresses in the new rail sections, and (c) continuation of the study of web stresses within joint bar limits.

Appendix 12–a

Effect of Bolt Spacing on Rail Web Stresses Within the Rail Joint

Summary

Tests were conducted in the laboratory at the University of Illinois to study the effect of bolt tension, applied wheel loads and bolt hole spacing, upon rail web stresses within the limits of the joint bar. Tests were made with bolt tensions of 10,000 lb., 20,000 lb. and 30,000 lb. Applied wheel loads produced reversed flexure of the rail joint corresponding to that under traffic, and also included eccentric loading. Three bolt spacings from the rail end were used as follows: (A) the present AREA recommendation of 2½ in.—6½ in.—6½ in.; (B) 3½ in.—6 in.—6 in.; and (C) 4½ in.—5½ in.—5½ in.

The rail used was the new 115-lb. RE section with 36-in. headfree joint bars and 1-in. diameter bolts.

Similar stress measurements were also made on two 131-lb. RE rail joints in tangent track during the passage of regular trains. These joints were 36-in. long of headfree design with 1-in. diameter bolts.

Tightening of the track bolts and the resultant wedging action of the joint bars within the rail fishing surfaces produced tensile stresses within the rail web in a vertical direction. This wedging force was usually unequal on the opposite faces of a rail end, and as a result a bending strain was developed, increasing the vertical tension on one face and decreasing it on the other. In addition the vertical tension was increased about three times in magnitude at the edge of a bolt hole due to the stress concentration effect of the hole. Irregularities in bearing contact at the fishing surfaces, such as pinching at the rail ends from the hot saws or bulges of the bar section at the punched holes, produced more than average wedging effect and vertical tension at certain areas, particularly near the rail end. As a result, vertical tensile stresses in the rail web that would be expected to be in the range of 15,000 to 20,000 psi. with 30,000 lb. bolt tension, were found to be as high as 50,000 to 70,000 psi. at the bolt holes. Moving the first bolt hole farther away from the high stress area near the rail end not only lowered the tension stress at the bolt hole, but also reduced the stress in the upper and lower fillets and web area at the rail end.

Providing a moderate bolt tension was maintained, the web stress was not much changed by the wheels of trains passing over the rail joints except in the upper web fillet near the rail ends. Here the possibility of the wheel bearing being eccentric towards either the gage or field side gives a range of stress under traffic from a high tension to a low tension or even compression, a range of stress which may produce fatigue failures. This high range of repeated stress in the upper web fillets at the rail ends helps to account for the occurrence of cracks in this area which have been reported by several railways. Lack of sufficient bolt tension results in a surprising amount of increase in the range of web stress under traffic.

Cracks which have occurred in service at the first bolt hole have evidently developed from an excessively high tension stress, perhaps aided by corrosive effects.

Laboratory fatigue tests in which the rail joint was subjected to reversed flexure as it would be under traffic conditions, showed that the fatigue strength of the joint is somewhat increased by moving the first bolt hole farther from the rail end.

The only disadvantage found in the tests of moving the first bolt hole farther from the rail end was that the stress at the last bolt hole was increased thereby. Some supporting power of the joint may also be lost, but it was not possible to determine this from the tests.

As a result of the tests, it is recommended that the present spacing of bolt holes at the rail ends, of 2½ in.—6½ in.—6½ in. be revised to 3½ in.—6 in.—6 in. for six-hole joint bars and from 2½ in.—6½ in. to 3½ in.—6 in. for four-hole joint bars.

Purpose of Test

On some railroads, cracks have developed in the upper web fillet at the rail end and also through the bolt hole nearest the rail end. Engineers closely associated with the problem feel that the proximity of the hole to the rail end is a factor in these failures.

The recent adoption of new rail sections by the AREA has made urgent the determination of the proper spacing of the drilled holes in the rail for the rail joint bolts. If improvements can be made in the spacing of the holes, it is very desirable that this revision be made before the new sections come into general use.

The stress distribution in the web of the rail within the joint bar limits is obviously complex. Accordingly it was decided that a preliminary test should be made, using Stresscoat over the entire web surface, to get a general picture of the stress distribution and to determine the areas of critical stress. These areas would then be studied more extensively with electrical strain gages on rail joints with different arrangements of bolt spacing to determine what bolt spacing provided the most favorable stress distribution.

The investigation was assigned to the Engineering Division research staff and is directed by E. E. Cress, assistant research engineer, under the general supervision of G. M. Magee, research engineer. Randon Ferguson, electrical engineer, and M. F. Smucker, assistant electrical engineer, conducted the laboratory and field tests. Funds were provided by the Association of American Railroads.

Preliminary Tests—Stresscoat

Tests were made on several rail joints using brittle lacquer (Stresscoat) in July 1946. This is a coating material that cracks after a certain elongation has been exceeded and thus serves to define high stress areas. The tests were made in a manner to show separately the effect of bolt tension and joint flexure on rail web stresses. The preliminary findings made from a study of the several tests were as follows:

1. The areas of greatest stress in the rail web were in the upper web fillet in the region of the rail end, around the end bolt hole, above the end bolt hole and in the lower web fillet near the end of the rail.

2. The direction of maximum stresses in the rail web was generally vertical, although there was some variation from the vertical.

3. The stresses in the rail web due to joint flexure were less than that due to the application of high bolt tension.

4. There was great variability in the magnitude of stresses at corresponding locations on the four web faces of the two rail ends of a joint due to variations in fit between the fishing surfaces of bars and rail.

Stress Concentration Due to a Hole

A brief consideration of the stresses that might be anticipated from a theoretical analysis will be helpful in explaining the data. This analysis consists of two principal parts. One part relates to the forces exerted on the rail ends by the joint bars and wheel loads and the other concerns the stress concentration around the bolt holes.

The presence of a hole in any member subjected to stress is a source of a considerable increase in stress locally around the hole. Seely (Advanced Mechanics of Materials) gives the following relation for the stresses, S_t, in the vicinity of a hole normal to the direction of principal stresses:

$$S_t = \frac{S_o}{2}\left(2 + \frac{r^2}{x^2} + 3\frac{r^4}{x^4}\right) \quad \ldots\ldots (1)$$

in which S_t is the stress at distance x from the center of the hole, S_o is the stress if the hole were not present, and r is the radius of the hole. The above equation is derived on the basis that the plate is of infinite width, but will apply with good accuracy if the distance from the center of the hole to the edge of the plate is greater than twice the radius of the hole.

The maximum stress is at the edge of the hole or at point x equals r and is

$$S_{max} = 3\ S_o \quad \ldots\ldots (2)$$

or a stress concentration of 3 due to the presence of the hole.

Several experimental methods used in checking the value of equation (2) have indicated that the actual concentration factor ($S_{max} \div S_o$) is close to 2. In most of the experimental methods the effect of a localized stress of high intensity would be minimized by local yielding or plasticity and the concentration factor apparently reduced. Photoelastic work indicates the same concentration factor as the mathematical analysis. Stress measurements within the circumference of the hole in the tests reported below by means of wire resistance gages have indicated stresses about three times those present between the holes, in conformity with the mathematical analysis and photoelastic work.

With a 1-in. bolt hole spaced 2½ in. from the rail end, formula (1) gives a stress S_t at the rail end equal to 1.022 S_o. The calculated stress directly at the rail end is therefore only increased about 2 percent due to the presence of the hole at this spacing.

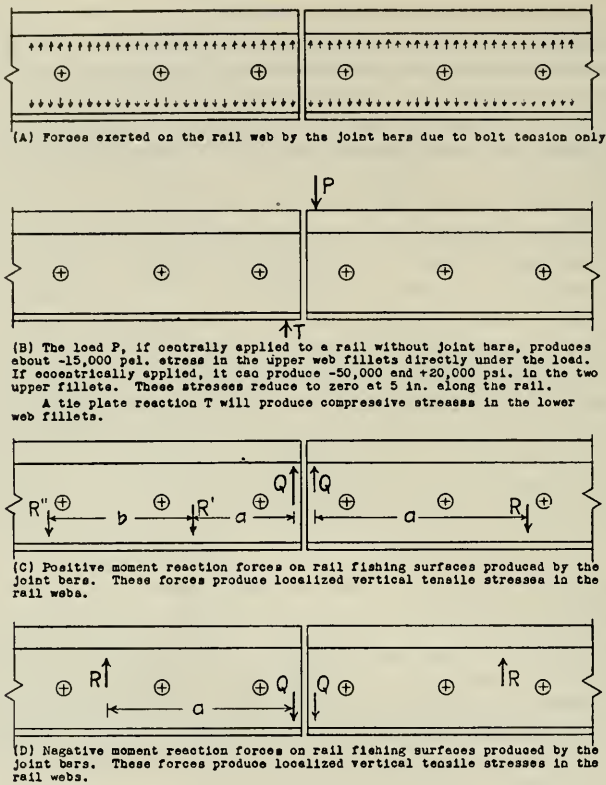
Thus, according to the theoretical formula, the localized stresses resulting from the presence of a bolt hole would not be appreciably affected by increasing the distance of the bolt hole from the rail end beyond the 2½ in. distance now generally used. However, as explained later, there is actually a benefit in increasing this distance because there is an area of above average web stress near the rail end due to the pinching of the rail ends from the hot saws, and the benefit results from moving the bolt hole farther away from this higher stressed area. It is also probable that the stresses resulting from the pinched rail ends may be somewhat reduced by having the holt hole farther from the rail end.

Forces Applied to the Rails within the Rail Joint

An understanding of the forces exerted on the rail ends by a rail joint with the different types of loading conditions imposed in track is necessary before the stress distribution in the rail web can be thoroughly understood. The Special Committee on Stresses in Railroad Track presented thorough studies of the action of the rail joint in the fifth, sixth and seventh progress reports, Proceedings, Vol. 31, 1930; Vol. 35, 1934 and Vol. 42, 1941. Only a brief review of the various types of forces and pressures exerted on the rail ends of a joint will be given here.

In (A) of Fig. 1 are sketched the forces exerted on the rail web by the joint bars due to the application of bolt tension only. The application of bolt tension tends to wedge the head and base apart which stretches the fibers of the rail web and produces vertical tensile stresses. In the sketch, these forces are shown as being uniform all along the top and bottom fishing surfaces. This is an optimum condition and would only be obtained when the vertical and lateral fit between rail and bar fishing surfaces is perfect and all bolts in a joint have the same tension. Imperfect fit of rail or bar fishing surfaces, wear of either rail or bar surface, rail ends pinched by the hot saws, swollen bar fishing surfaces above and below the punched holes and unequal tension in the several bolts will tend to make these pressures nonuniform along the fishing surfaces. On most new rail and bars, there is a concentration of pressure in the upper web fillets at the rail ends.

The sketch (B) of Fig. 1 shows the load P on the rail head and a tie plate reaction T on the rail base. Either of these forces applied at any position along the rail, will tend to produce vertical compressive stresses in the rail web near the point of load application. The load P, if centrally applied to a rail without joint bars, produces 10,000 to 15,000 psi. vertical compression stress in the upper web fillets directly under the load. If the load P is eccentrically applied at the rail head, it can produce—50,000 and + 20,000 psi. stress in the two upper web fillets. At bolt hole height, even if the load P is eccentrically applied and some additional lateral load is present, the vertical stress at one web face will not be greater than — 25,000 psi. All these stresses reduce to zero at



(A) Forces exerted on the rail web by the joint bars due to bolt tension only.

(B) The load P, if centrally applied to a rail without joint bars, produces about -15,000 psi. stress in the upper web fillets directly under the load. If eccentrically applied, it can produce -50,000 and +20,000 psi. in the two upper fillets. These stresses reduce to zero at 5 in. along the rail.

A tie plate reaction T will produce compressive stresses in the lower web fillets.

(C) Positive moment reaction forces on rail fishing surfaces produced by the joint bars. These forces produce localized vertical tensile stresses in the rail webs.

(D) Negative moment reaction forces on rail fishing surfaces produced by the joint bars. These forces produce localized vertical tensile stresses in the rail webs.

Fig. 1.—Forces Exerted on Rail Ends Due to a Variety of Loading Conditions.

5 in. longitudinally along the rail. The tie plate reaction T (usually not over one-third the magnitude of the load P) will produce compressive stresses in the lower web fillets and a very low vertical compressive stress at bolt hole height.

Sketch (C) shows the positive moment (load P applied anywhere within the joint bar length) reaction forces on the rail fishing surfaces produced by the joint bars. The bars act as beams with loads or vertical forces applied to the top fishing surfaces of the bar by the under side of the rail head for short distances back from the rail ends as indicated by the reaction force Q, and with forces applied by the lower fishing surfaces of the bar to the rail base at points R or R' and R''. The force Q at each rail end can range from 30,000 to 70,000 lb. This force tends to produce a very high localized vertical tensile stress in the upper web fillets at the rail end.

The negative moment reaction forces on rail fishing surfaces produced by the joint bars are shown in (D) of Fig. 1. The force Q applied near the rail end at the lower web fillet tends to produce localized vertical tensile stresses in this web area. These forces should never be greater than half as much as the other set of forces produced by positive moment.

On a rail joint loaded with positive bending moment, any combination of forces in sketches (A), (B) and (C) in Fig. 1 may be present on the rail. With negative moment, any combination of the forces in sketches (A), reaction T of (B) and (D) may be present.

In this discussion, a lateral force applied to a rail joint has not been considered. If the bolts are tight, the rails and two joint bars will act as one unit laterally and have considerable stiffness. Therefore, the rail web faces being near the vertical neutral axis of the rail and bars, should not be highly stressed due to a lateral load.

I. Measurements of Rail Web Stresses Within the Rail Joint—Laboratory Tests

Description of Tests

A series of 200 tests were made on rail joints in the Talbot Laboratory of the University of Illinois from February 20 to April 10, 1947. The new 115-lb. RE rail section with 36-in. headfree bars was principally used for the tests to study the effect of bolt spacing. Three pairs of rail ends and bars with the centerline of the end bolts drilled 2½ in. from the rail end are termed the "A" joints (this conforms to AREA recommended drilling). Another three pairs of joints with the end holes drilled 3½ in. from the rail ends are termed the "B" joints. A third three pairs of joints with the end holes drilled 4½ in. from the rail ends are termed the "C" joints. The drilling dimensions are shown in Fig. 2. These rails and bars were furnished through the courtesy of the Colorado Fuel & Iron Co. The rail ends were milled off by the steel company as is their usual practice. Due to the method of group selection, all rail ends and all bars should have as good a fit if interchanged as is possible with commercial rails and bars.

Rail web stresses were also measured on 112-lb. RE rail ends using both 24-in. head contact bars and 24-in. headfree bars with central overfill. The 112-lb. RE rail was drilled for 2½-in.—6½-in. bolt hole spacing.

SR–4 wire resistance gages of ¼-in. gage length were applied to all four rail web faces of the two rail ends of a joint. The static strains were read with a Baldwin–Southwark portable strain indicator. A rail joint was first assembled and 10,000, 20,000 and 30,000 lb. bolt tension was applied to the 1-in. bolts and the magnitude of the rail web stresses measured. The rail joint was then placed in a 33-in. stroke rolling-load machine where both positive and negative bending moments were applied to the joint and the rail web stresses measured. Eccentric loads were also applied to the joint to determine the maximum range of stress that would be expected to occur under loading conditions that occur in track.

Position of Maximum Stresses in Rail Web

A comprehensive stress survey was first made on one of the A series of joints by placing 17 strain gages on one web face of one rail end at the positions shown in Fig. 3. Preliminary measurements had shown that the stresses in the web face selected were higher than at either of the other three rail web faces. Stresses were then measured with loading conditions to cover the range that would be imposed in track, including 30,000 lb. bolt tension only, 30,000 lb. bolt tension combined with + 400,000 in. lb. positive moment and the same bolt tension with — 200,000 in. lb. negative bending moments. From these data shown in Fig. 3 and other tests, including the Stresscoat, it was decided that gages placed vertically on each of the four rail web faces within each test joint at positions 1, 2, 3, 12A and 22A would cover the significant stress areas.

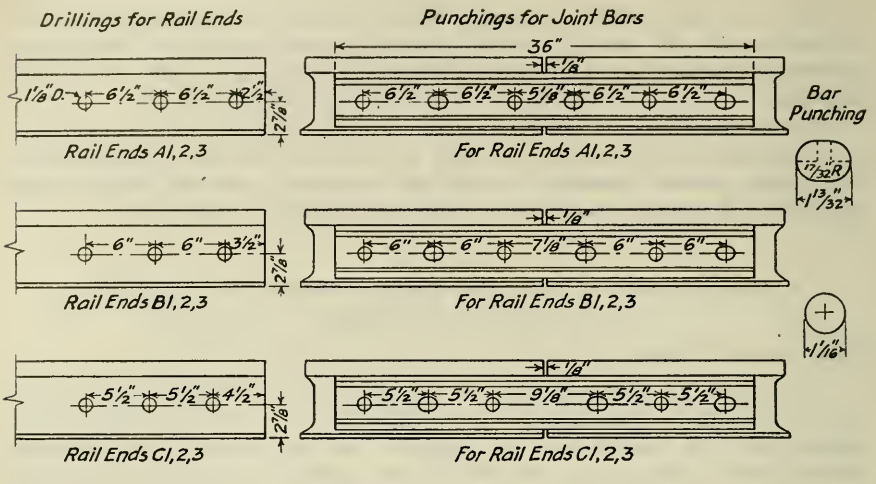


Fig. 2.—115-lb. RE Rail Ends and 36-in. Headfree Joint Bars with the Three Bolt Hole Spacings A, B and C Used in the Laboratory Tests.

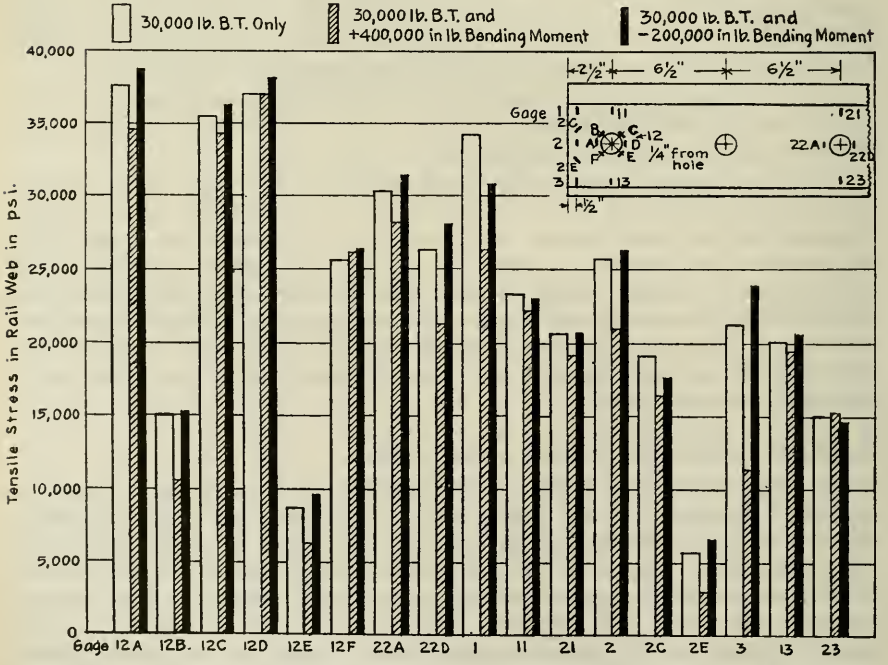


Fig. 3.—Stresses in Southeast Web Face of 115-lb. RE Rail Ends (A1) with 36-in. Headfree Bars (A1) Due to 30,000-lb. Bolt Tension Only and for 400,000 in.-lb. Positive and 200,000 in.-lb. Negative Bending Moment.

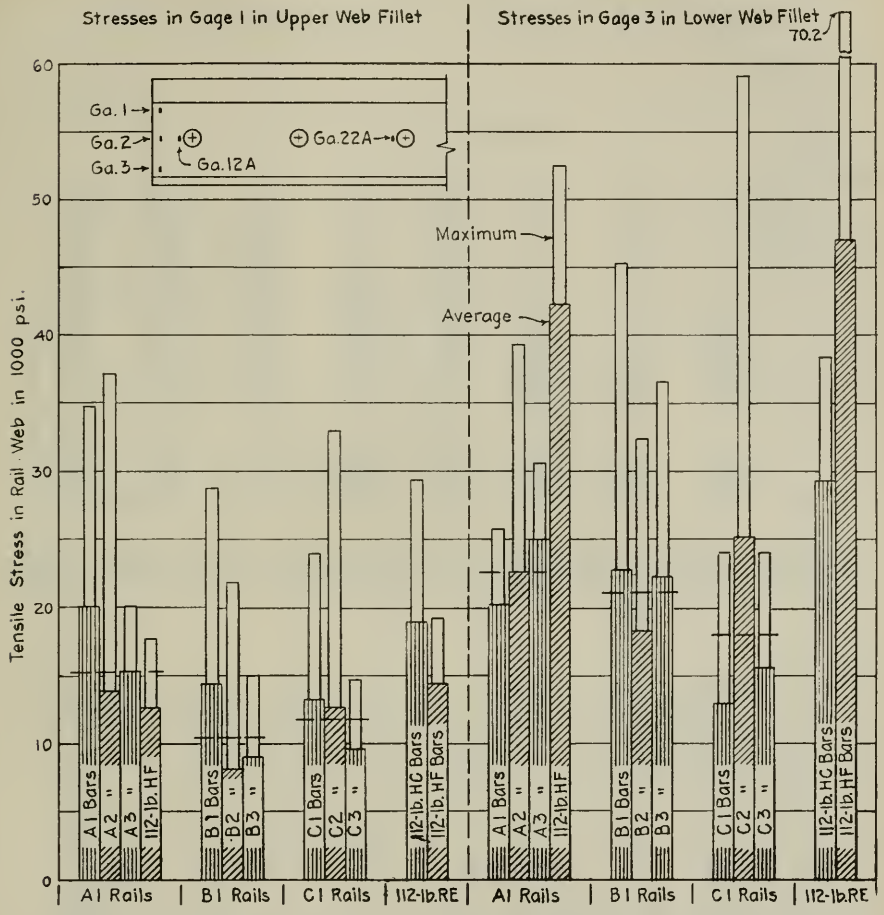


Fig. 4.—Maximum and Average Stress in the Four Gages 1 in Upper Web Fillets and in Gages 3 in Lower Web Fillets of 115-lb. RE Rail Ends with 36-in. Headfree Bars Due to 30,000-lb. Bolt Tension Only—Three Bolt Hole Spacings A, B and C.

Rail Web Stresses Due to Bolt Tension Only

It is interesting to note in Fig. 3 that the applied bolt tension is of far more importance in producing rail web stress than the flexure of the rail joint. Accordingly, Figs. 4 to 8 have been prepared to show for each gage location a comparison of the stresses resulting from an applied bolt tension of 30,000 lb. for the different bolt spacings and types of joint bars used. A bolt tension of 30,000 lb. was used as approximating the maximum amount that would ordinarily be applied in track service.

In the left half of Fig. 4, stresses measured at the four gage 1 positions in the upper web fillet ½ in. from the rail ends are shown for the various test joints. Bars A1, A2, A3 and 112-lb. headfree bars were applied to the A1 rail ends and tested. Bars as indicated were also applied to B1, C1 and 112-lb. RE rail ends. The wider, shaded rec-

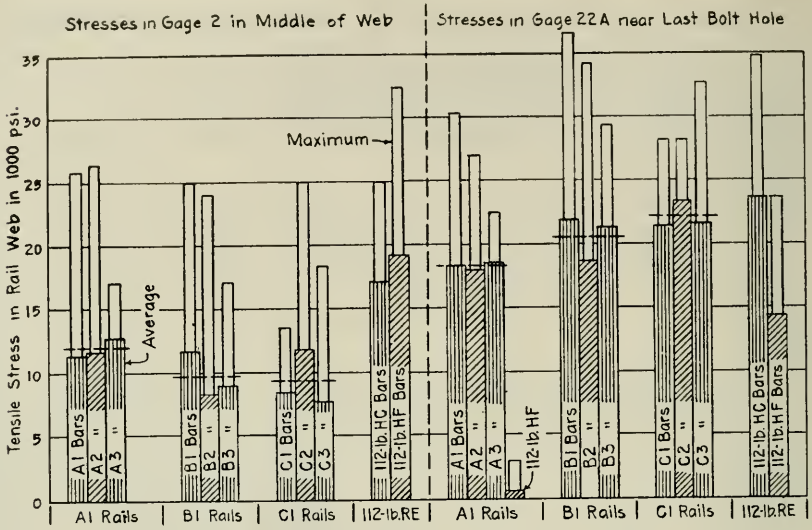


Fig. 5.—Maximum and Average Vertical Stress in the Four Gages 2 and in Gages 22A in Webs of 115-lb. RE Rail Ends with 36-in. Headfree Bars Due to 30,000-lb. Bolt Tension Only—Three Bolt Hole Spacings A, B and C.

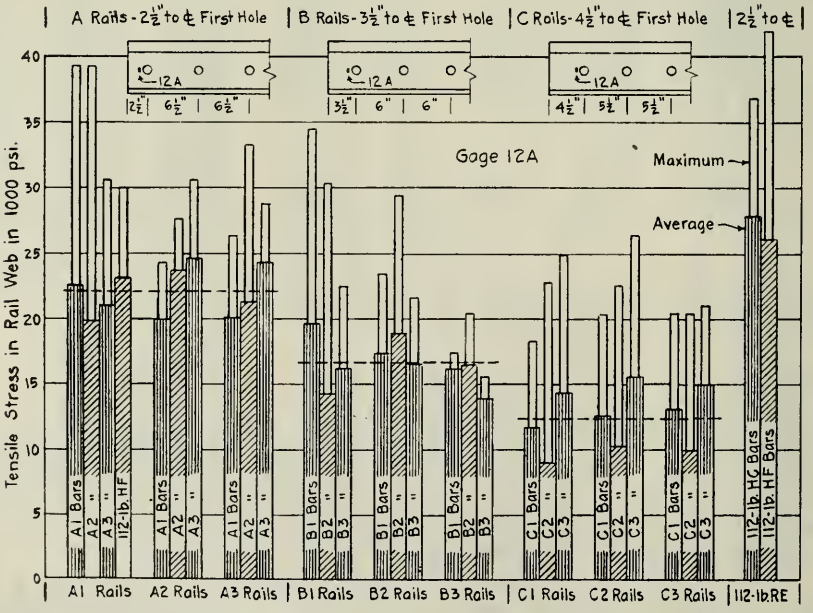


Fig. 6.—Maximum and Average Stress in the Four Gages 12A Near End Bolt Holes in Webs of 115-lb. RE Rail Ends with 36-in. Headfree Bars Due to 30,000-lb. Bolt Tension Only—Three Bolt Hole Spacings A, B and C.

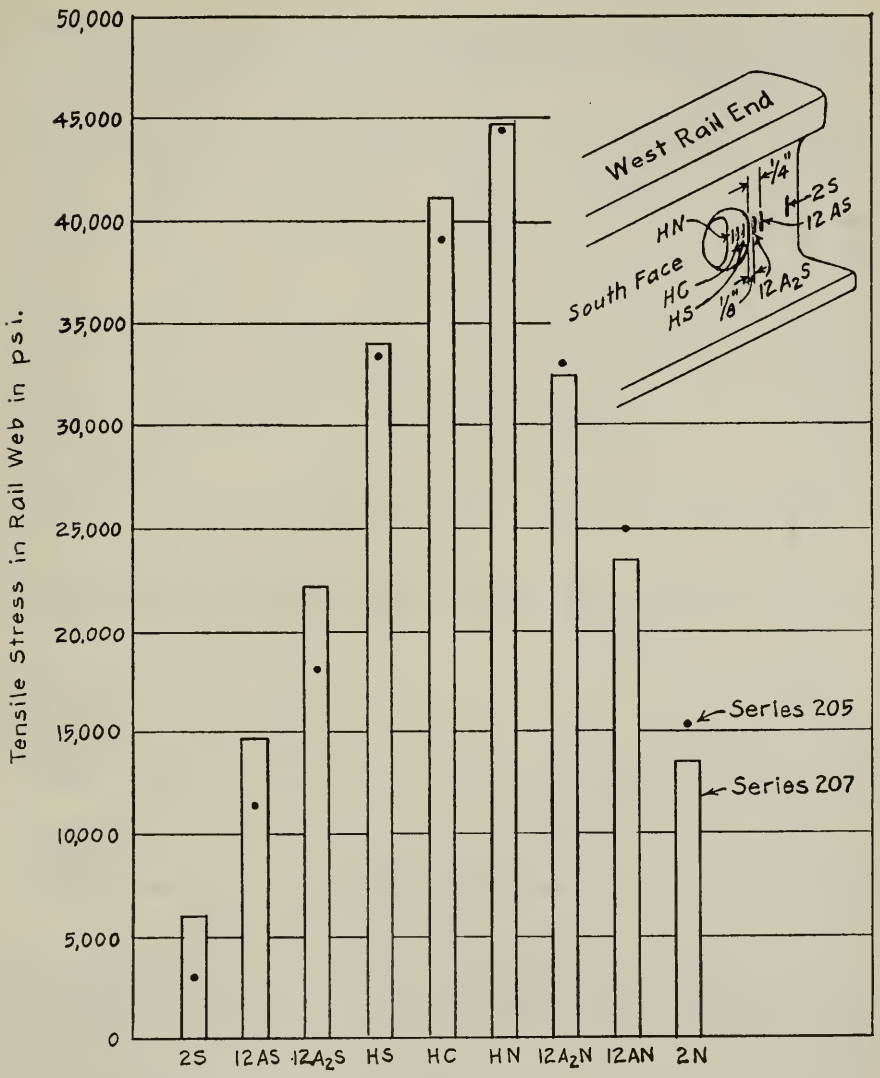


Fig. 7.—Stresses in 115-lb. RE Rail Web (A1) Near End Bolt Hole with 36-in. Headfree Bars (A1) Due to 30,000-lb. Bolt Tension Only.

tangles in the lower part of the figure indicate the average stress at the four gage 1 positions of a joint. Most weight should be given these average stresses in comparing one type of bolt hole spacing with another. The narrow rectangles represent the maximum stress recorded at any individual gage positions, a value that is highly dependent upon joint fit and subject to wide variation in succeeding applications of the same pair of joint bars to a pair of rail ends. The magnitude of the stress at gage 1 is important because this is one of the rail web areas in which cracks have actually developed in service.

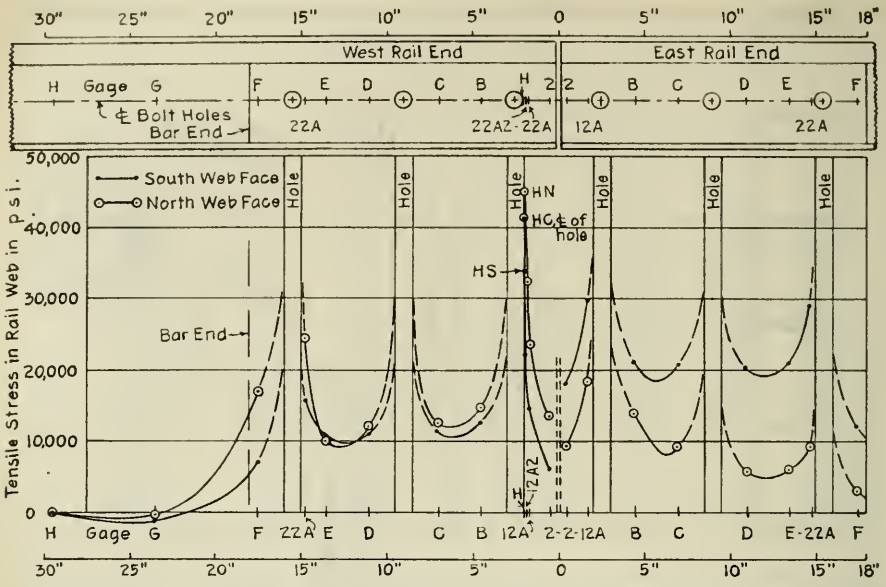


Fig. 8.—Vertical Stresses Along Centerline of Bolt Hole Height of 115-lb. RE Rail Web (A1) with 36-in. Headfree Bars (A1) Due to 30,000-lb. Bolt Tension Only.

Measured stresses are shown in the same manner in Figs. 4 and 5 for gages 2, 3 and 22A. Gage 2 is at the middle of the rail web and gage 3 in the lower web fillet, both being ½ in. from the rail end. Gage 22A is ¼ in. from the edge of the last bolt hole and gage 12A is placed in a corresponding position at the first bolt hole. There are four gages of each of the above numbers for each rail joint tested.

For gage 12A, the stresses recorded are shown in Fig. 6. Rail end cracks have also been reported at this location. Because of the importance of this location, the A1, A2 and A3 rail ends were tested in succession with the A1, A2 and A3 bars to give the effect of nine rail joints of the A type; the B and C types were similarly tested.

It will be noted that the effect of increasing the distance of the bolt hole from the rail end tends to lower the stress at gages 1, 2, 3 and 12A, but tends to increase the stress at gage 22A. The stress due to applied bolt tension would apparently be made equal if the first bolt hole were spaced 3 in. from the rail end, or half way between the A and B spacings.

Concentration of Stress Around Bolt Holes

The considerably higher stress at gage 12A near the first hole than at gage 2 which is only a little more than 1 in. away, made it appear desirable to explore the stress distribution around the bolt hole more thoroughly. Accordingly, additional gages were placed around an A rail end at the locations shown in Fig. 7. The stress rises very rapidly for gage 12A (¼ in. from the edge of the drilled hole) to within the hole. Gages HS, HC and HN were placed within and on the circumference of the drilled hole, then the bolt was carefully inserted. For five tests, the maximum stress within the hole ranged from 2.03 to 2.16 times the average stress in gages 12AS and 12AN. In the two series of Fig. 7, the stress at ⅛ in. from the hole is 1.4 times the stress at ¼ in. from

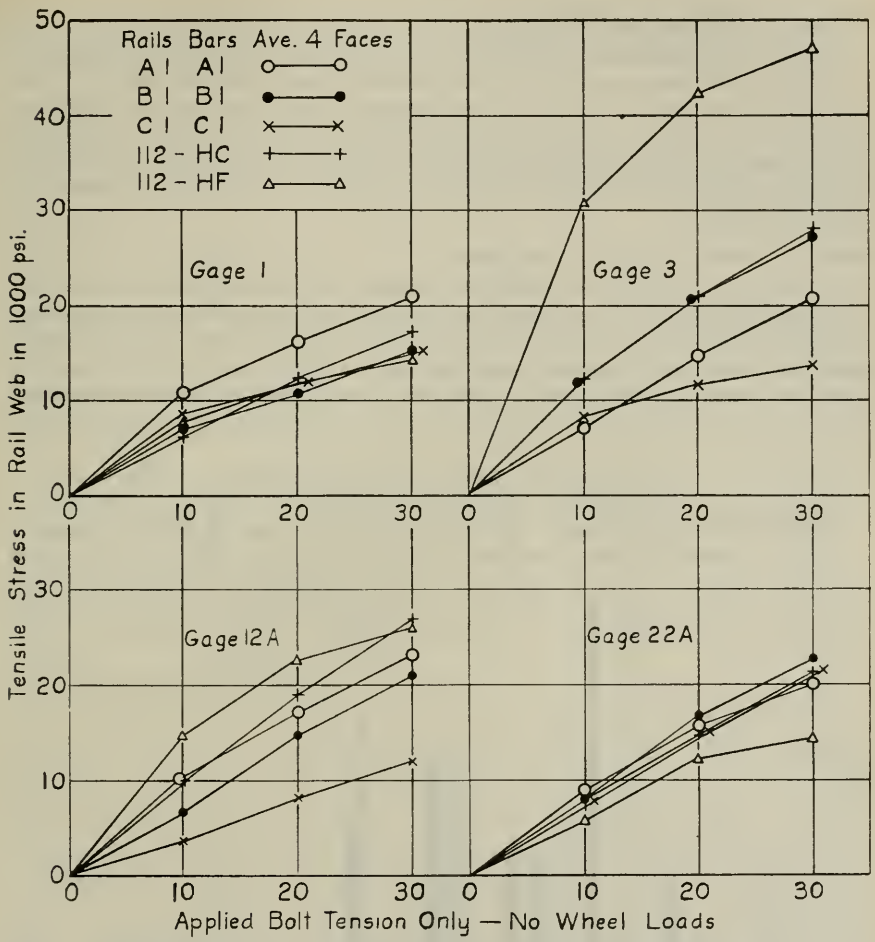


Fig. 9.—Average Stress in Four Gages in the Four Web Faces of Rail Ends Due to the Application of 10,000, 20,000 and 30,000-lb. Bolt Tension Only.

the hole. These ratios should closely apply to all rail ends, regardless of the bolt hole spacing. Stresses within the end bolt holes of the rails shown in Fig. 6 would be expected to be double the average stresses reported in gage 12A. For example, the tensile stress within the end holes of all 18 A type rail ends of Fig. 6 would probably average 45,000 psi. For five tests, the maximum stress within the end bolt hole averaged 1.75 times the higher of the companion stresses in gage 12A on the north or south face of the web. Therefore, it would be expected that for the A1 rail with either the A1 or A2 bars (Fig. 6), the maximum tensile stress in one bolt hole due to 30,000 lb. bolt tension only, would have been 69,000 psi. (39.300 × 1.75.)

Fig. 8 is presented to give a picture of the vertical tensile stress distribution at each of the two web faces of the rail ends along the centerline of the bolt hole height due to 30,000 lb. bolt tension only. At only one end bolt hole were there gages closer than ¼ in. to the hole. The concentration of stress at the bolt holes is quite marked and the magnitude is sufficient to be of concern.

Effect of Different Bolt Tensions

So far the discussion has been limited to the rail end stresses due to the application of 30,000 lb. bolt tension only. In Fig. 9 are plotted average stresses for gages 1, 3, 12A and 22A for five types of rail ends for the application of 10,000, 20,000 and 30,000 lb. bolt tension. For the A1, B1 and C1 type rail ends, for gage 1 in the upper web fillet, a bolt tension of 10,000 lb. produces about half as much average stress as a tension of 30,000 lb. At gage 12A for the type B and C rail ends, the average stress is proportional to the bolt tension.

Effect of Other Types of Joint Bars

In Figs. 4, 5, 6 and 9 are plotted the stresses for the 112-lb. RE rail ends with 24-in. head contact and 24-in. headfree bars with central easement and lateral overfill. For gage 1, the average stresses are about the same as for the A type rails. For gages 2 and 12A the stresses are somewhat higher than for the other types of rails. For gage 22A (near the second bolt hole with the 24-in. bars) the stresses are in the same general range as for the other types of rail ends. The 24-in. headfree bars with overfill produce

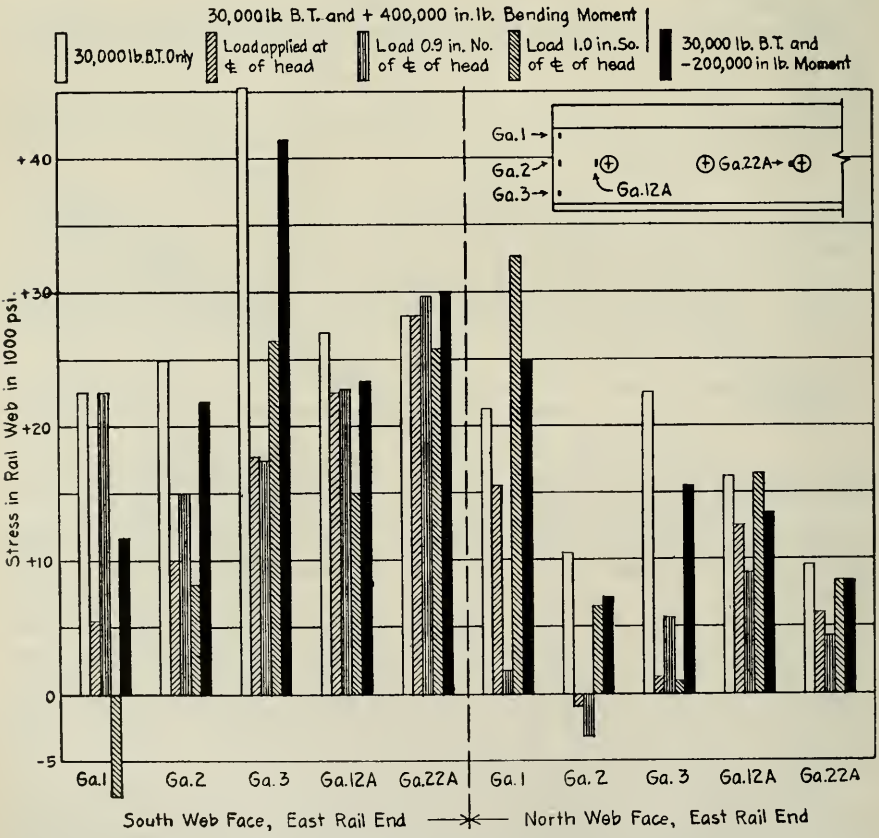


Fig. 10.—Range of Stress at Five Gages in the North and South Web Faces of the East Rail End (B1) with 36-in. Headfree Bars (B1) Due to 30,000-lb. Bolt Tension and to Different Conditions of Loading.

a very high stress in gage 3 in the four lower web fillets of the rail ends, on both the 112-lb. RE and 115-lb. RE rail ends. It seems probable that the central overfill will produce high stresses at some location in the end of a new, unworn rail.

Rail Web Stresses Due to Application of Loads

The preceding discussion has presented the data showing the effect of applied bolt tension on rail web stresses. In addition to the effect of bolt tension, the effect of loading must be considered because it is important at certain gage positions. Fig. 10 shows the measured stress at five gages on the opposite web faces for one of the B type rail ends for bolt tension and different conditions of loading.

Measurements were made with positive and negative bending moment to determine the effect of joint flexure combined with applied bolt tension. With the positive moment, the load was also applied eccentrically approximately 1 in. each side of the centerline of the rail head as this condition of eccentricity of loading is also common in track. The range of the measured stress at any gage location for the different loading conditions is indicative of the range of repeated stress that would occur in track.

It is interesting to note that only gages 1 and 3 show a range of stress of appreciable magnitude; generally the tensile stress due to the applied bolt tension is reduced by the applied loading. At gage 1, the effect of eccentricity of loading results in considerable stress change and one gage shows a stress reversal into compression. At gage location 3, the positive bending moment reduces the applied tension by a considerable amount. Additional data on the stress range at gage 3 are given in Fig. 11, which shows the important effect of a centrally applied positive bending moment in reducing the applied tension and of the negative moment in increasing it, especially at low applied bolt tensions.

Fig. 12 shows the range of repeated stress in gages 1, 3, 12A and 22A due to 30,000 lb. bolt tension and to all the different conditions of loading on the five types of rail joints. This range would correspond to the range between the highest and lowest stress for a gage in Fig. 10. The wide rectangles represent the average range of stress in the four web faces and the narrow rectangles represent the maximum range in one face. For gage 1 (plotted in the lower part of the figure) for direct comparison of all five types of joints, the range is taken as the difference between the stresses with the eccentric loads bearing equally on the two rail ends and corrected to eccentricities of exactly 1 in. north and south of the middle of the rail heads. The average stress range for gage 1 is practically the same for the different bolt spacings for the 115-lb. RE joints, but is much higher for the 112-lb. RE rail with 24-in. headfree bars with lateral overfill.

At the upper left side of Fig. 12, plotted in dashed lines, is the total range of repeated stress for gage 1 for the C1, 112-lb. RE rail with head contact and headfree bars for the eccentrically applied loads of about 1 in. first placed all one one rail end, then on both rail ends, then all on the other rail ends. These special loadings were not applied to the A1 and B1 type joints. For each of these three types of joints, the eccentric loads all on first one rail end and then the other increase the average stress range in gage 1 by from 10,000 to 11,000 psi. Gage position 1 is the only area in the rail web that is affected by these special types of loadings. It is reasonable to assume that had these extra loadings been applied to the A1 and B1 type joints, their average stress range in gage 1 would have also been increased by about 10,000 psi.

The repeated stress range for gage 3 in the lower web fillet due to loadings is also shown in Fig. 12. The ranges vary slightly for the different bolt spacings.

The repeated stress range due to loadings is also given in Fig. 12 for gages 12A and 22A, located near the bolt holes. Provided there is a considerable tension in the

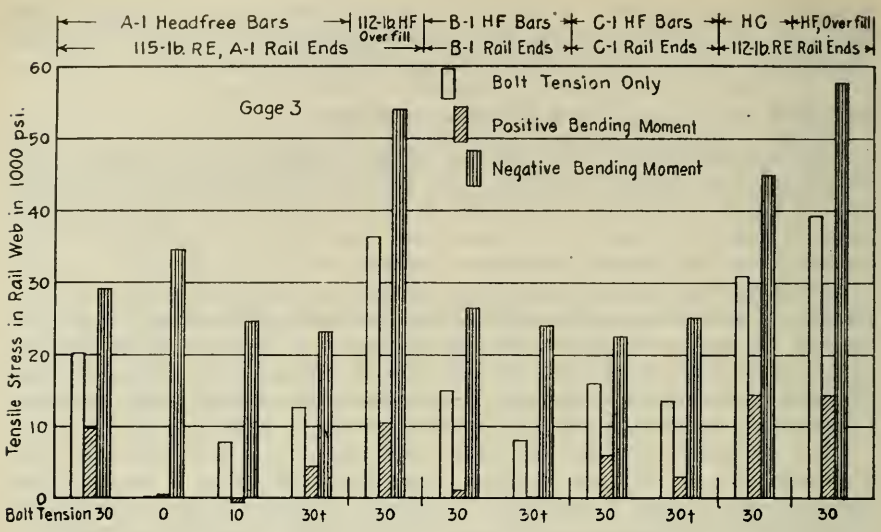


Fig. 11.—Average Stress in Gage 3 in Lower Fillet at the Two Web Faces of West Rail Ends for Bolt Tension Only and for 400,000 in.-lb. Positive and 200,000 in.-lb. Negative Bending Moment—† Intermediate Bolts Removed.

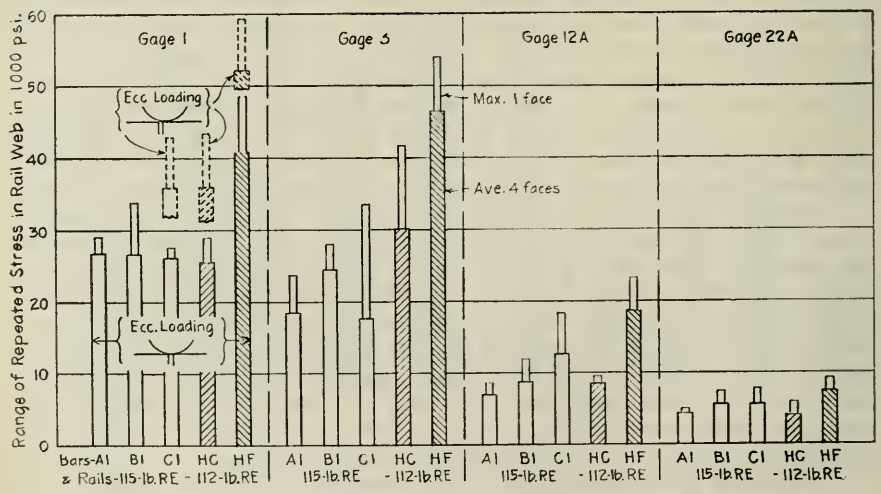


Fig. 12.—Maximum Range and Average Range of Repeated Stress in Four Gages in the Four Web Faces of Rail Ends Due to 30,000-lb. Bolt Tension and to Different Conditions of Loading—Laboratory Tests.

bolts, the repeated stress range in the area near the bolt holes is very small due to any type of loading applied. This is fortunate because it has been shown that the stresses at these positions can be high due to the application of bolt tension.

The foregoing data make it possible to understand how cracks could develop from repeated stress in service in the upper web fillets at the rail ends. The measured stress range in the lower fillets is almost as high, but no cracks have been reported. Cracks have also been reported around the end bolt hole where the repeated stress range is low, although the tensile stress due to applied bolt tension is quite high.

Results of Rolling-Load Tests

After completing the stress measurements, each of the A, B and C rail joints were tested to failure in the rolling-load machines at the University of Illinois to determine whether the change in bolt hole spacing would affect the fatigue life of the joint in reversed flexure. The individual test results are shown in Table 1. It will be noted from the table that for each of the nine joints failure occurred upward from the base of one bar, within the spacing of the middle bolt holes of the bar. No cracks developed in any of the rail ends.

From Table 1 it is seen that the three A type rail joints averaged 533,600 cycles at failure, ranging from 359,200 to 800,600 cycles. The three B type rail joints averaged 677,000 cycles at failure, ranging from 492,700 to 810,500 cycles. The three C type rail

TABLE 1.—ROLLING-LOAD TESTS OF 115-LB. RE A, B, & C TYPE RAIL JOINTS

44,400-lb. load. Max. positive bending moment 400,000 in. lb. Max. negative bending moment 200,000 in. lb.

Bolt Tension: 15,000 lb. Bolts 1 in. diam., heat-treated, prestressed.

Type & No. of Joint	*Cycles for Failure*	*Hardness—BHN Base of*		*Bar Failure—Location of Crack N = north, S = south*
		N. Bar	*S. Bar*	
A1 (115)	800, 600	232	231	S. bar—Base—2 in. E. of gap. Vertical, then 90 deg. into hole.
A2 (123)	440, 900	193	224	S. bar—Base—¾ in. outside of inner bolt hole.
A3 (124)	359, 200	205	268	N. bar—Base to inner hole. Also fatigue area at bar hole.
	Avg. 533, 600			
B1 (116)	810, 500	237	241	S. bar—Base to inner hole. Also fatigue area at hole.
B2 (125)	492, 700	217	226	N. bar—Base—2¾ in. E. of gap.
B3 (127)	727, 700	227	256	N. bar—Base to inner hole. Also fatigue area at hole.
	Avg. 677, 000			
C1 (117)	1, 060, 800	239	244	S. bar—Base—2½ in. W. of gap.
C2 (126)	1, 081, 000	266	262	S. bar—Base to inner hole. Also fatigue area at hole.
C3 (129)	307, 500	248	234	N. bar—Base—¾ in. W. of gap.
	Avg. 816, 400			

Magnaflux examination detected hairline cracks due to rail end gouging on the top fishing surfaces of six base failed bars listed below:

A1 S. bar—½-in. crack in gouge of east rail end.
A2 S. bar—⅜-in. crack in gouge of east rail end.
B3 N. bar—two ⅜-in. cracks, both in gouge of east rail end.
C1 S. bar—¾-in. crack in gouge of east rail end.
C2 S. bar—two ½-in. cracks in gouge of each rail end.
C3 N. bar—¾-in. crack ¼ in. from gouge of west rail end.

joints averaged 816,400 cycles at failure, ranging from 307,500 to 1,081,000 cycles. The range of cycles at failure for each type of joint is large, but not greater than for a number of former types of joints tested.

Although there is a considerable variation in the number of cycles required for failure of individual joints in each of the three drilling arrangements, nevertheless there is a definite indication that the fatigue life of the joint bar is increased as the spacing between the two middle bolt holes is increased.

II. Measurements of Rail Web Stresses Within the Rail Joint—Tangent Track

Description of Tests

In July 1947, after the completion of tests to determine the impact effect of flat spots on car wheels on the Chicago & North Western Railway near Harvard, Ill., the dynamic stress recording equipment was used to measure the rail web stresses in two consecutive rail joints in tangent track. Two months before this test, a few new 131-lb. RE rail had been laid in the tangent track for the impact tests. The rails were drilled for the AREA recommended spacing of 2½—6½—6½ in. The new joint bars were head-free bars 36 in. in length with 1-in. bolts. Seventeen SR–4 wire resistance gages of ¼ in. effective length were attached to the four web faces of the two rail ends of each joint. Gage 1 was placed in the upper web fillet and gage 3 in the lower web fillet, each 3/16 in. from the rail end (see Fig. 13). Gage WHC was placed within the end bolt hole of the west rail end. Gages 12 and 22 were placed ⅛ in. from the edges of the end and third bolt holes in the rail ends. As these gages are only ⅛ in. from the holes, it is to be expected that they would record a stress 1.4 times greater than if located

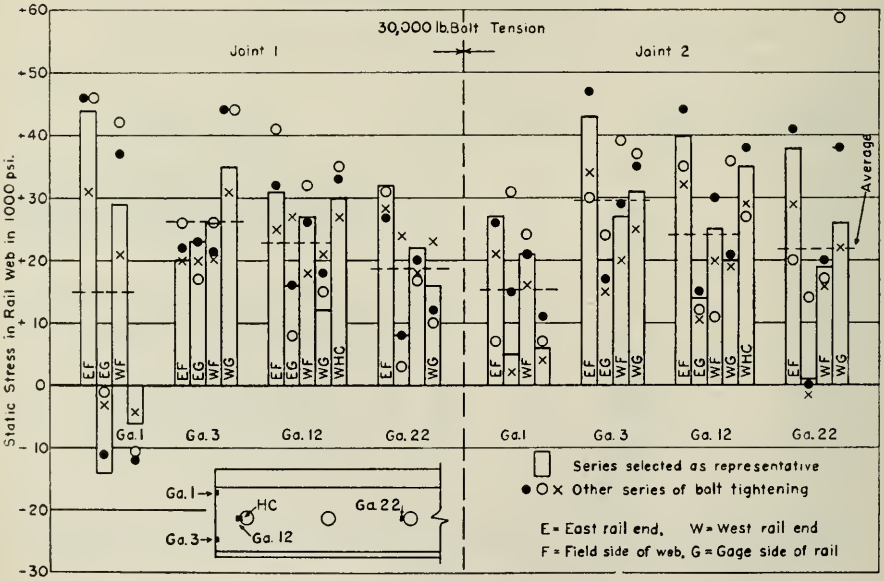


Fig. 13.—Static Stress at Four Gage Locations in Each of the Four Web Faces of 131-lb. RE Rail Ends with 36-in. Headfree Bars Due to 30,000-lb. Bolt Tension Only—Joints 1 & 2—C. & N. W. Tangent Track.

¼ in. from the holes as in the laboratory tests. All stresses discussed are in a vertical direction in the rail webs within the joint bar length; none is in the joint bars.

Static stresses in the rail webs due to the application of bolt tension were measured by a Baldwin–Southwark portable strain indicator. The additional dynamic stresses produced by each wheel of passing trains were recorded on two oscillographs containing magnetic galvanometers. From each test run record, the maximum tensile and compressive dynamic stress at each gage location was determined for the locomotive and tender and also under the wheels of the cars of the trains.

At each joint, tensions of 30,000 and 20,000 lb. and zero were set in the bolts, and records under four or five regular trains were made for each tension. Locomotives running over this track were mostly of the Pacific, Mikado, and diesel classes. Some of the freight trains had a few heavy coal cars and there were quite a number of heavy carloads of rock. Train speeds ranged between 25 and 70 mph.

Rail Web Stresses Due to Bolt Tension Only

At the left side of Fig. 13 is shown the measured stresses produced in joint 1 by tightening the bolts to 30,000 lb. tension; corresponding measurements for joint 2 are shown at the right side of the figure. As in the laboratory tests, it was found that when the bolts were loosened, the bars reapplied and the bolts retightened to the same tension, the measured stress at each gage would be considerably diffrent. To illustrate this, four sets of measurements with successive reapplication of the bars with 30,000 lb. bolt tension are shown in the figure. In addition, stress values for corresponding gage positions on each of the four rail end web faces show considerable difference. One reason for this is an unequal wedging action of the bars on the two sides of the rail resulting in a bending strain on the web. In one instance, the bolt tightening produced a tensile stress of 44,000 psi. and a compressive stress of 14,000 psi. at the gage 1 positions on opposite web faces of the same rail end. Another reason is a possible difference in fishing heights of two abutting rail ends, resulting in higher web stresses in the rail end with the lesser fishing height. Other reasons have been previously mentioned. All gage positions show a maximum tension of 40,000 to 50,000 psi. on one joint or the other due to the applied bolt tension of 30,000 lb.

For both joints the stress within the end bolt hole is 1.5 times the stress just ⅛ in. from the edge of the hole. This agrees closely with the laboratory measurements shown in Fig. 7.

Rail Web Stresses Due to Wheel Loads

At each joint, dynamic stresses were recorded under four or five trains with a tension in the bolts of 30,000 and 20,000 lb. and zero. The stresses recorded under trains by the stress measuring equipment in the track tests do not include the initial stresses due to the tension set in the bolts. Therefore for a true condition of the stress range, the dynamic stress must be plotted above and below the initial stress produced by the bolt tension. Fig. 14 shows the maximum range of dynamic stress recorded under trains and the static stress due to 30,000 lb. bolt tension. The static stresses are the same set of stress values plotted in Fig. 13, and the values of the dynamic stress have been algebraically added to them. For example, gage 1 on the field face of the west rail end of joint 1 has a initial stress of + 29,000 psi. due to bolt tension. The maximum dynamic stresses recorded by this gage under trains were + 23,000 and — 31,000 psi. The dynamic stress range is therefore from + 52,000 to — 2000 psi. This is the maximum range of stress recorded at this gage under four trains. The stress range is high in gage 1 in the upper web fillets at the rail ends. At some of the gage 1 positions, the high repeated stress range is all or almost all in tension, which can be considered more likely to produce

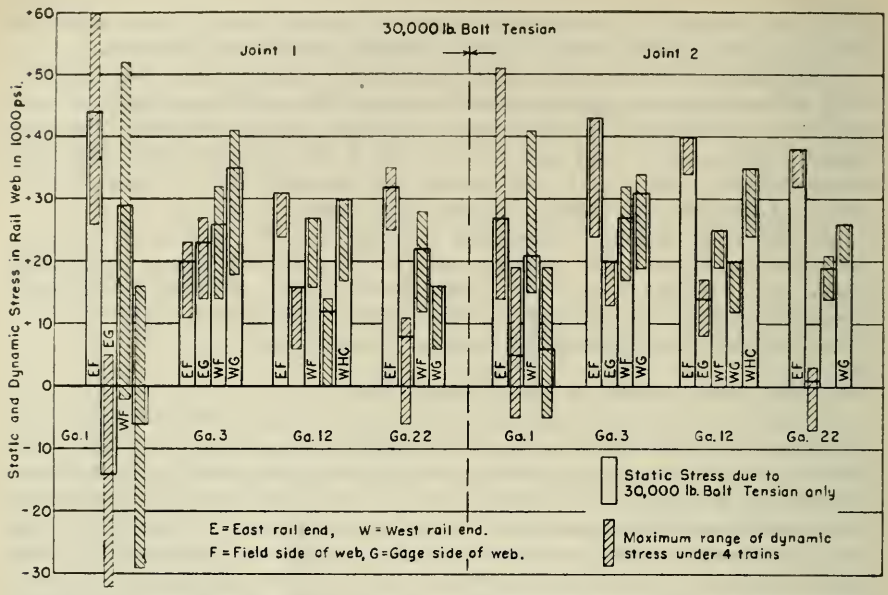


Fig. 14.—Maximum Range of Dynamic Stress under Four Trains Superimposed on Static Stress Due to 30,000-lb. Bolt Tension in the Four Web Faces of 131-lb. RE Rail Ends with 36-in. Headfree Bars—Joints 1 & 2—C. & N. W. Tangent Track.

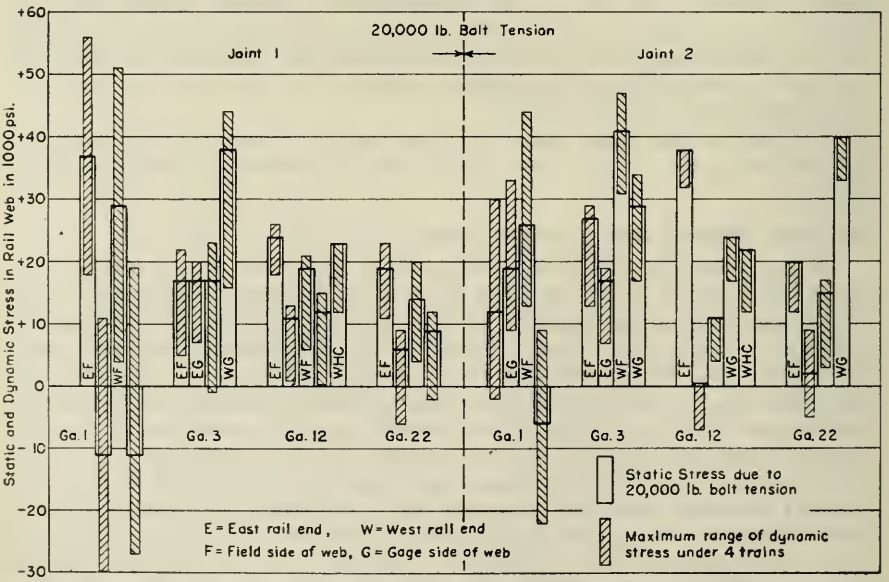


Fig. 15.—Maximum Range of Dynamic Stress under Four Trains Superimposed on Static Stress Due to 20,000-lb. Bolt Tension in the Four Web Faces of 131-lb. RE Rail Ends with 36-in. Headfree Bars—Joints 1 & 2—C. & N. W. Tangent Track.

fatigue cracks than repeated compressive stress of equal magnitude. In former tests, high upper web fillet stresses outside of the rail joints produced by eccentric loads were largely in compression.

The range of repeated stress for gage 3 in the lower web fillet (shown in Fig. 14) can be considered low. It is lower than the range reported in the laboratory tests. The range of repeated stress in gages 12 and 22, located at the edges of the bolt holes, is also shown in Fig. 14. These stress ranges are quite low with the high bolt tension. At only a few of these positions is there any dynamic tensile stress.

Fig. 15 shows joints 1 and 2 set with 20,000 lb. bolt tension and the stresses under the trains added to them as before. The stresses due to bolt tension are in general not quite as high as for the higher bolt tension (30,000 lb.) shown in Fig. 14, but the patterns are similar. The dynamic stresses and the stress ranges are quite similar to the values for the higher tension.

Fig. 16 shows the same two test joints set with zero bolt tension. The joint bars fitted well into the rail fishing surfaces and the nuts were turned up to a position where tension would have been applied if they had been further turned. After a train had passed, the bars were found to be still free and therefore no residual stress was set up in the rail web due to bolt tension. With this condition existing, the maximum dynamic stresses recorded under the trains can be plotted from the zero line. The maximum range of stress at gage 1 position is very high. The average range for all eight gages is 60.000 psi., and at one gage the range was 71,000 psi. The tensile stress reaches 50,000 psi. If this stress range is repeated often enough, upper web fillet cracks would be expected to occur at these 131-lb. RE rail ends on tangent track with the zero bolt tension. It is evident that maintenance of bolt tension in rail joints is very beneficial with respect to the range of dynamic stresses.

The stress range for gage 3 in the lower web fillet with zero bolt tension is also shown in Fig. 16. These stress ranges are low, they are no higher than with the high bolt tensions. The stress ranges for gages 12 and 22 are about triple the ranges for the higher bolt tensions. An examination of the records shows the reason for this greater stress range. If a considerable tensile stress was recorded on a gage on the field web face under a given wheel, the companion gage on the opposite gage web face always produced compression. This denotes a bending strain on the rail web. The maintenance of a moderate bolt tension would have caused the bars to support the rail head and prevented the greater part of the bending strain. Gage WHC, within and at the center of an end bolt hole of joint 1, had less stress range than the companion gage 12 on the web faces. Being on the vertical neutral axis, this gage was not influenced by the bending strain on the rail web.

Fig. 17 compares the range of repeated stress under trains in gages 1, 3, 12, WHC and 22 of joints 1 and 2 on tangent track for the three conditions of bolt tension. The wide rectangles are the averages of the stresses at the four gage faces at each of the two joints. The narrower rectangles are the highest stresses recorded at one of these web faces. These values are the averages and maximum of the shaded rectangles in Figs. 14, 15 and 16. At gage 1 in the upper web fillet at the rail end, the stress range may be considered high with the higher bolt tensions, and with the zero bolt tension, the stress range is so high as to make fatigue failures seem likely. At gage 3 in the lower web fillet at the rail end, the stress range is low for all three conditions of bolt tension. This range is considerably lower than the corresponding range found in the laboratory tests. With the bolt tensions of 20.000 and 30,000 lb., the range of repeated stress was very low at gages 12, WHC and 22 (near and within the bolt holes). This is fortunate because the stresses at the bolt holes are often high due to the application of a high bolt tension.

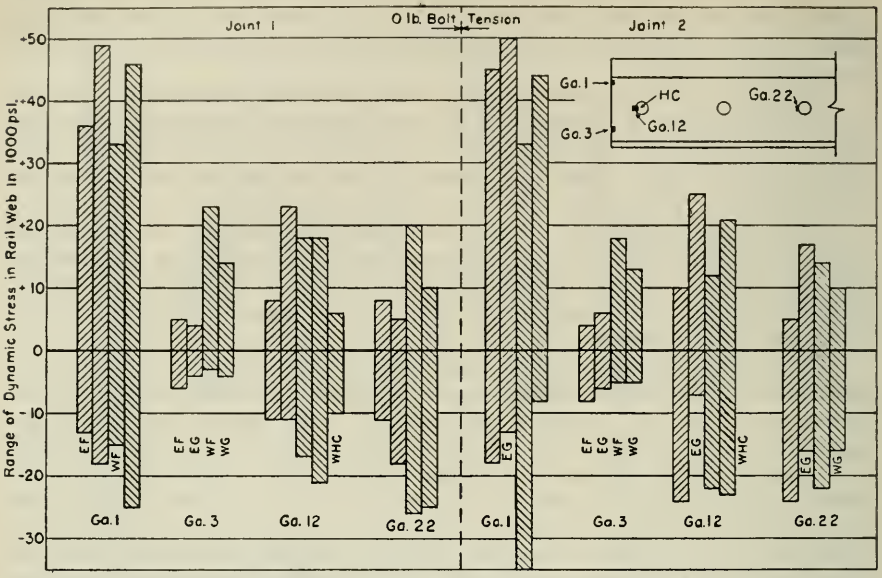


Fig. 16.—Maximum Range of Dynamic Stress under Four Trains in the Four Web Faces of 131-lb. RE Rail Ends with 36-in. Headfree Bars with no Bolt Tension—Joints 1 & 2—C. & N. W. Tangent Track.

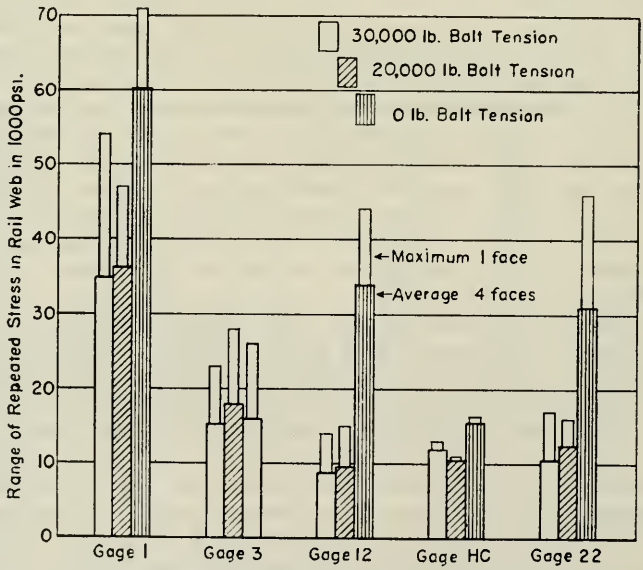


Fig. 17.—Maximum Range and Average Range of Repeated Stress under Trains in the Four Web Faces of 131-lb. RE Rail Ends with 36-in. Headfree Bars Due to Various Bolt Tensions and to Different Conditions of Loading—Joints 1 & 2—C. & N. W. Tangent Track.

Conclusions

1. High intensities of tensile stress in a vertical direction are produced at the bolt holes and in the upper and lower fillets at the rail end when the track bolts are tightened to a tension approaching the upper range of that used in track. Increasing the distance from the rail end to the first bolt decreases this stress intensity at all areas where cracks have occurred in service, but increases it somewhat at the last bolt hole.

2. The effect of passing wheel loads with track bolts moderately tight produces a significant range of stress which might develop fatigue failure only in the upper web fillets near the rail end. Increasing the spacing of the first bolt hole does not change this range of stress, but does reduce the maximum tensile stress developed in the range so that fatigue failures are less likely to develop. Lack of adequate bolt tension has a very severe effect in increasing this range in the upper and lower fillets at the rail end and also at the bolt holes.

3. Rolling-load tests on assembled rail joints, subjected to reversed flexure as they are in track, indicated an increase in fatigue life of the bars as the distance from the rail end to the first bolt hole is increased.

4. There was no significant difference in the amount of rail end batter or joint deflection in the rolling-load tests with the various bolt spacings.

Recommendations

It is recommended that the present spacing for bolt holes at the rail end be changed from 2½ in.—6½ in.—6½ in. to 3½ in.—6 in.—6 in. for six-hole joints and from 2½ in.—6½ in. to 3½ in.—6 in. for four-hole joints.

Appendix 12–b

Fatigue Tests of Rail Webs

By R. S. Jensen

Special Research Associate Professor of Engineering Materials, University of Illinois

The study of the fatigue strength of rail webs has been continued; as reported in the Proceedings, Vol. 48, 1947, pages 804–808, corrosion fatigue tests were made on T-shaped specimens cut from the web of a 112 lb.-RE rail under bending stresses ranging from a maximum compressive stress to a tensile stress 20 percent as great. A very active solution of 36 percent sulfuric acid was used as a corroding agent and was allowed to drip at the rate of 10 drops per min. on the specimens.

In addition, corrosion fatigue tests were made on three groups of painted specimens designated as group 1, group 2, and group 3, in order to test the practicability of different types of paint as protective coatings for rails in tunnels, highway crossings, and other places where corrosion fatigue failures are likely to occur. R. P. Winton, testing engineer, maintenance of way, Norfolk & Western Railway, at whose suggestion the tests were made, arranged to have the specimens painted, and furnished the following data and analysis of the paints used.

Group 1, Specimens 46 to 55

One coat of P–245–Y alkyd primer of the following composition:

	Lb.	Bulk	Gal.
Zinc yellow Y–539–D	296	0.0343	10.2
Hydrated iron oxide	53	0.0304	1.6
Magnesium silicate	128	0.0421	5.4
Alkyd resin solution (50% solids)	460	0.125	61.0
Mineral spirits	140	0.152	21.3
6% Cobalt naphthenate	3	0.125	0.4
24% Lead naphthenate	9	0.105	0.8
	1089		100.7

The second coat was P–246–BR which was exactly the same as the first coat except red iron oxide (75 percent Fe_2O_3) was substituted for the hydrated iron oxide in the above formula.

The third coat was P–250–BL as follows:

	Lb.	Bulk	Gal.
Carbon black	50	0.0671	3.5
Alkyd resin solution (60% solids)	617	0.131	80.0
Mineral spirits	120	0.152	18.3
24% Lead naphthenate	14.0	0.105	1.5
6% Cobalt naphthenate	5.0	0.125	0.7
	860.0		104.0

Each of these coats had a 1.5 mils dry film thickness on the flat surfaces, giving a total average film 4.5 mils thick.

Group 2, Specimens 56 to 65

One coat of P–247–Y having the following composition:

	Lb.	Bulk	Gal.
Zinc yellow Y–539–D	346	0.0343	11.9
Hydrated iron oxide	62	0.0286	1.9
Magnesium silicate	150	0.0421	6.3
Phenolic resin solution (60% solids)	455	0.130	59.2
Mineral spirits	128	0.152	19.5
24% Lead naphthenate	6	0.105	0.6
6% Cobalt naphthenate	2	0.125	0.3
	1149		99.7

The second coat was P–248–BR which was exactly the same as the first coat except red iron oxide (75 percent Fe_2O_3) was substituted for the hydrated iron oxide in the above formula.

The third coat was P–249–BL having the following composition:

	Lb.	Bulk	Gal.
Carbon black	50	0.0671	3.5
Phenolic resin solution (60% solids)	610	0.130	79.0
Mineral spirits	120	0.152	18.3
24% Lead naphthenate	14.0	0.105	1.5
6% Cobalt naphthenate	5.0	0.125	0.7
	799.0		103.0

All coats had a 1.5 mils dry film thickness on the flat surfaces, giving a total average film 4.5 mils thick.

Group 3, Specimens 66 to 75

One coat—wash primer—19 percent solids pigmented vinyl resin solution.

Two coats—red lead—vinyl resin primer which is an 18 PV 100 percent red lead pigmented paint carrying a vehicle composed of a copolymer type vinyl resin cut with suitable solvents and thinners.

One coat—finish coat paint M5076 which is pigmented with carbon black, red lead, and extender pigments. The vehicle is composed of a medium length drying oil alkyd, a chlorinated diphenyl resin, and chlorinated rubber.

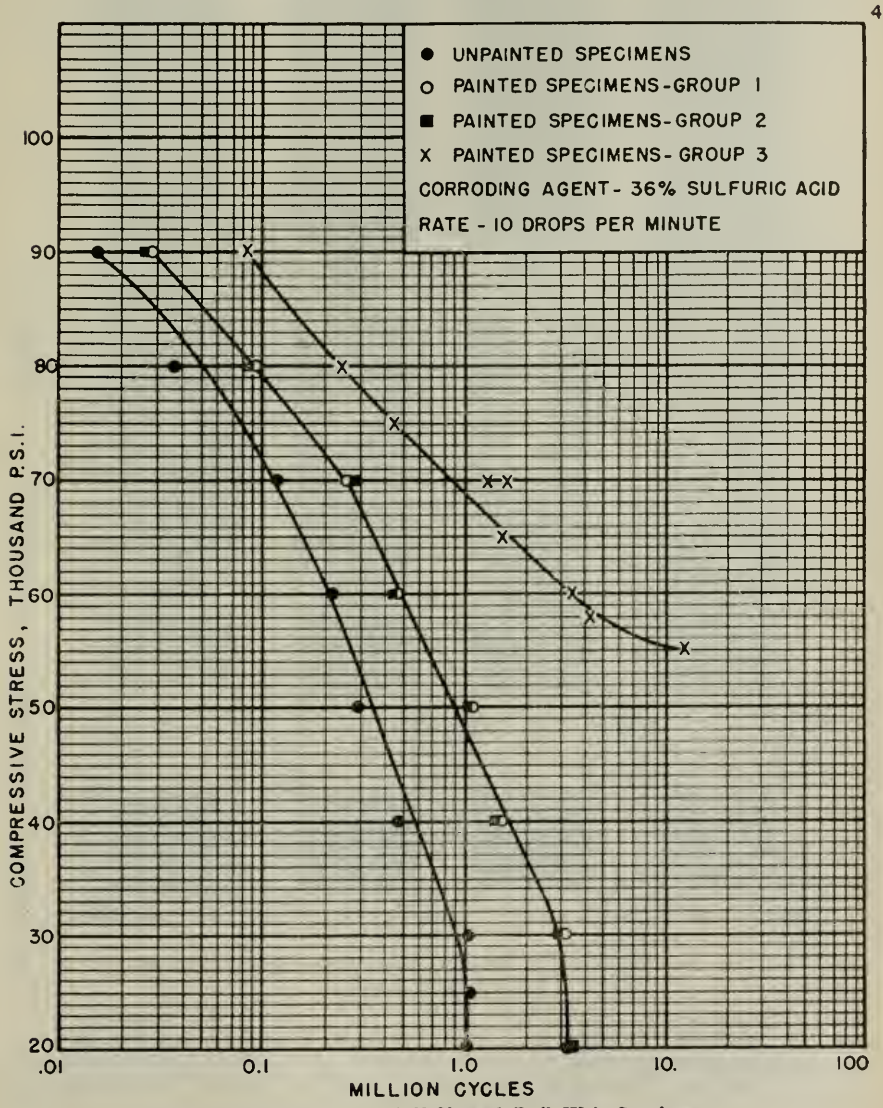


Fig. 1.—Fatigue Tests of T-Shaped Rail Web Specimens.

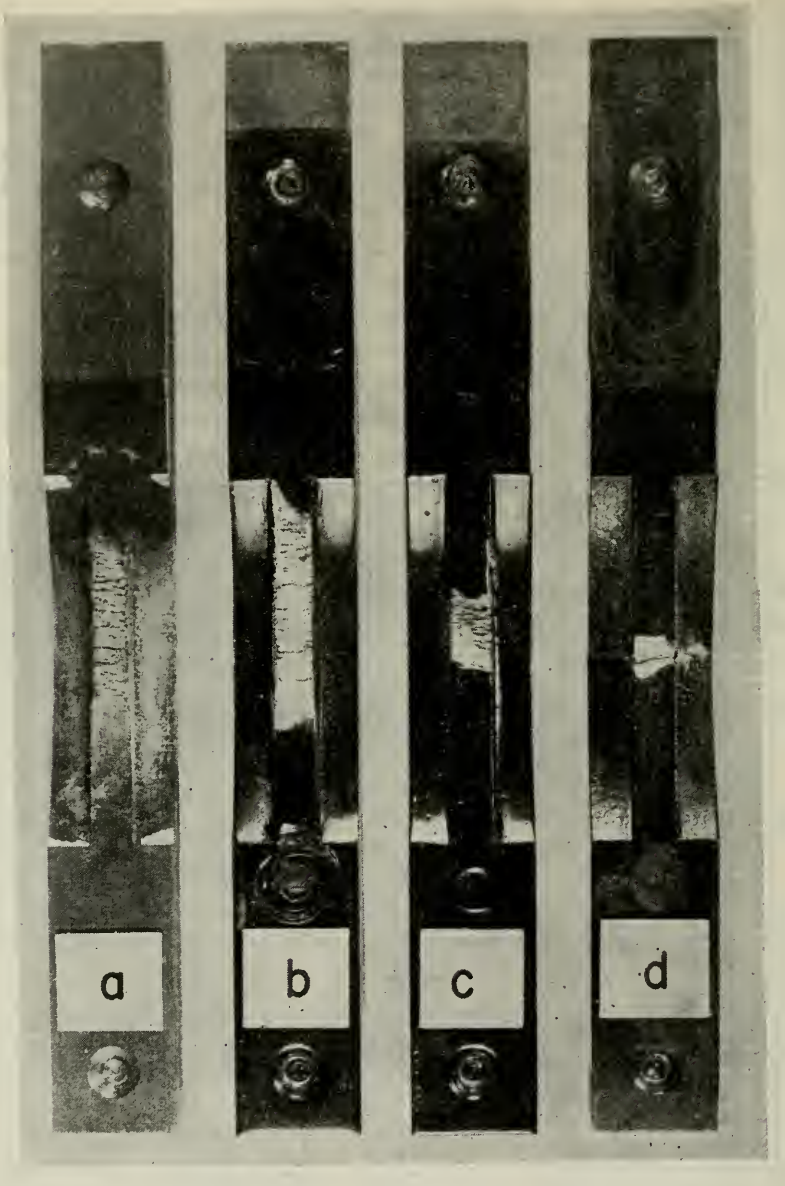


Fig. 2.—T-Shaped Rail Web Specimens Tested Under 36 percent Sulfuric Acid Solution.

(a) Specimen 36—unpainted ..... 40,000 psi.
(b) Specimen 51—group 1 ..... 40,000 psi.
(c) Specimen 61—group 2 ..... 40,000 psi.
(d) Specimen 72—group 3 ..... 55,000 psi.

The total average film thickness was 4.93 mils. Fig. 1 shows the S. N. curves for these three groups of painted specimens as well as the curve for the unpainted specimens for comparison. This data appears in tabulated form in Table 1. The curves for group 1 and group 2 indicate that these paints approximately doubled the fatigue life of the specimens at the higher stresses (above 60,000 psi.) and tripled it at the lower stresses (50,000 psi. and below) over the unpainted specimens with the acid corrosion. No appreciable difference in fatigue life was noted between the specimens of group 1 and those of group 2. For the most part, at higher stresses the paints on these two groups showed a tendency to form small blisters, while at the lower stresses the paint along the upper edge or corner of the T-shaped specimen cracked open first.

TABLE 1.—DATA ON CORROSION FATIGUE TESTS

Specimen Number	*Compressive Stress, psi.*	*Cycles to Start Crack*
Unpainted Specimens		
23	90, 000	15, 800
24	80, 000	36, 600
33	70, 000	119, 500
34	60, 000	215, 100
37	50, 000	291, 000
36	40, 000	489, 500
38	30, 000	1, 010, 500
39	25, 000	1, 138, 000
40	20. 000	1, 027, 400
Painted Specimens		
Group 1		
46	90, 000	28, 100
54	80, 000	93, 500
48	70, 000	253, 500
49	60, 000	477, 400
50	50, 000	1, 155, 500
51	40, 000	1, 700, 600
52	30, 000	3, 133, 000
53	20, 000	3, 153, 000
Group 2		
56	90, 000	25, 800
57	80, 000	85, 600
58	70, 000	273, 700
59	60, 000	442, 400
60	50, 000	1, 008, 800
61	40, 000	1, 532, 000
62	30, 000	3, 079, 000
63	20, 000	3, 485, 000
Group 3		
66	90, 000	81, 500
67	80, 000	234, 200
74	75, 000	447, 500
68	70, 000	1, 230, 000
70	70, 000	1, 664, 300
73	65, 000	1, 635, 000
69	60, 000	3, 452, 000
71	58, 000	4, 189, 900
72	55, 000	12, 066, 800

The specimens of group 3 showed a greatly increased fatigue life under the acid corrosion, withstanding from 2 to 7 times as many cycles of stress as the specimens of groups 1 and 2, and unlike them, this third group indicated an endurance limit in the vicinity of 55,000 psi. For this group of specimens (group 3) the paint seemed tough

and elastic and showed no tendency to form small blisters. The indications are, that for this group, the paint did not crack until the specimen itself had cracked, whereas for the other two groups the paint failed before the specimen cracked. The specimens of group 3 in the range of stress from 50,000 psi. to 80,000 psi., ran for a slightly greater number of cycles than the unpainted, unstamped, specimens with no acid corrosion reported last year. This may be due either to normal scatter caused by irregularities of the as-rolled surface, or possibly to the fact that the cracks in these specimens could not be detected at their very beginning because of the coating of paint.

Fig. 2 shows four of the specimens tested, one from each group of painted specimens and one unpainted specimen for comparison.

Fourteenth Progress Report of the Cooperative Investigation of Failures in Railroad Rails In Service and Their Prevention

Conducted by

The Engineering Experiment Station, University of Illinois

In Cooperation with

The Association of American Railroads

and

The American Iron & Steel Institute

By R. E. Cramer

Special Research Associate Professor of Engineering Materials, University of Illinois

I Introduction

Scope of the Investigation

Control cooling of railroad rails used by all United States mills since 1936 has reduced the number of transverse fissure failures to about 20 per year. A careful examination is made at the University laboratory of all rail failures which are classified by the railroads as transverse fissures. The results of these examinations are included in this report.

A major part of the research of this cooperative investigation consists of laboratory rolling-load tests to find a type of rail steel to resist shelling failures which occur in rails on curves. The report on this work is published as a part of Assignment 11 of AREA Committee 4—Rail.

Some work is continuing on end-hardened rails. A proposed recommendation for end hardening of rails was included in the Twelfth Progress Report published in AREA Proceedings, Vol. 47, 1946, page 473. Further field tests are proposed of end-hardened rails when the rail mills have progressed farther with installation of end hardening processes.

Advisory Committee

The sponsors of this work are represented by advisory committees consisting of the following engineers:

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American Iron and Steel Institute—Technical Committee on Rails:

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T. S. Washburn, Assistant Manager, Metallurgical and Inspection Department, Inland Steel Company

Acknowledgment.—The writer wishes to acknowledge the valuable services of M. C. Moore, mechanician in the laboratory shops and of T. S. Noggle and Frank Bolda, student assistants, who have helped in the laboratory tests.

II Examination of Control Cooled Rails Which Failed in Service

From September 1946 to September 1947, 42 control cooled rails were sent to the University laboratory for examination and classification. Table 1 summarizes the causes of failure and Table 2 lists each rail separately.

Table 1.—Summary of Control Cooled Rail Failures

Transverse fissures from hot torn steel	20
Detail fracture from shelling	12
Head and web separation from corrosion	3
Vertical split head	2
Detail fracture from engine burn	2
Transverse fissure from welded engine burn	1
Transverse fissure from shatter crack	1
Base break at seam	1
Total	42

It will be noted that a new term "hot torn steel" has been used. This type of head defect has been called "porosity" for the past three years and previous to that the same defect was called "blow holes." The mills now feel certain that the cause of this condition, as illustrated in Fig. 1, is a tearing of the steel during rolling when a portion of the rail bloom has been reheated too hot for successful rolling. The terms "hot tear" or

TABLE 2.—FAILED CONTROL COOLED RAILS EXAMINED AT TALBOT LABORATORY, UNIVERSITY OF ILLINOIS, FROM SEPTEMBER 1, 1946 TO SEPTEMBER 1, 1947

D. F. = Detail fracture T. F. = Transverse fissure V. S. H. = Vertical split head

Source of Failed Rail	*Laboratory Failed Rail No.*	*Size of Rail*	*Mill*	*Heat No. Rail Letter and Ingot*	*Date Rolled*	*Classification of Failure*
I. C.	479	112	Inland	16845–A–8	3/1943	D. F. from shelling
C. B. & Q.	480	131	Gary	35293–E–6	6/1936	Head and web separation from corrosion
C. B. & Q.	481	131	Inland	17453–D–4	11/1938	Head and web separation from corrosion
C. B. & Q.	482	131	Inland	22813–F–13	11/1938	Head and web separation from corrosion
N. & W.	484	131	Steelton	81697–C–15	12/3/1945	V. S. H. from oxide inclusion
S. P.	485	112	Steelton	88220–A–4	5/1938	T. F. from hot torn steel
B. & L. E.	486	131	Edgar Thomson	210057–E–12	4/1938	Base break at seam
D. & H.	487	112	Steelton	82338–G–9	7/1943	T. F. from hot torn steel
Southern	488	131	Steelton	87173–	4/1941	T. F. from hot torn steel
S. A. L.	494	100	Tennessee	873898–C–	6/1940	D. F. from shelly spot
S. A. L.	495	100	Steelton	81314–	5/1941	T. F. from hot torn steel
N. Y., N. H. & H.	496	131	Steelton	88206–D–4	4/1943	T. F. from hot torn steel
N. Y., N. H. & H.	497	131	Steelton	84116–B–15	3/1941	D. F. from shelling
R. F. & P.	498	131	Steelton	81289–D–6	7/1937	T. F. from hot torn steel
P. & L. E.	499	131	Edgar Thomson	208178–B–2	4/1941	D. F. from shelling
P. & L. E.	500	131	Edgar Thomson	205156–E–20	4/1940	D. F. from shelling
N. Y. C.	505	127	Lackawanna		5/1939	D. F. from wheel burn
N. & W.	506	131	Steelton	83164–B–16	3/1942	T. F. from hot torn steel
I. C.	507	112	Inland	36502	8/1941	D. F. from shelling
N. Y. C.	508	127	Gary	65302–E–1	9/1938	T. F. from S. C.
Southern	510	131	Steelton	84282–B–11	6/1943	T. F. from hot torn steel
C. & O.	511	131	Inland	20209–E–4	1/1938	D. F. from shelling
C. & O.	512	112	Inland	15168–D–3	1/1938	D. F. from shelling
S. P.	513	131	Steelton	85002–A–8	1938	T. F. from hot torn steel
N. & W.	514	131	Steelton	84096–E–4	2/1942	T. F. from hot torn steel
C. & O.	515	131	Inland	20385–B–12	1/1941	D. F. from shelling
L. V.	516	131	Lackawanna	22472–C–3	8/1943	T. F. from hot torn steel
B. & O.	517	131	Steelton	89635–B–6	11/1941	T. F. from hot torn steel
C. & O.	518	131	Gary	36007–B–3	1/1940	T. F. from welded engine burn
C. & O.	519	131	Steelton	86405–E–9	11/1935	T. F. from hot torn steel
C. & O.	520	131	Steelton	86344–F–1	10/1935	D. F. from shelling
C. & O.	521	131	Inland	23261–G–1	1/1941	V. S. H.
C. & O.	522	131	Inland	31222–E–7	2/1941	T. F. from hot torn steel
C. & O.	523	131	Inland	21569–E–7	7/1945	T. F. from hot torn steel
C. & O.	524	131	Inland	30042–D–4	2/1941	T. F. from hot torn steel
C. & O.	525	131	Inland	30042–A–8	2/1941	T. F. from hot torn steel
C. & O.	526	131	Steelton	81077–B–12	2/1940	T. F. from hot torn steel
N. Y., N. H. & H.	527	131	Steelton	86217–F–15	4/1937	D. F. from shelling
D. & H.	528	112	Steelton	88225–G–3	1940	D. F. from shelling
M. P.	530	112	Colorado	4446–C–10	8/1944	D. F. from engine burn
B. & M.	531	112	Steelton	86205–C–3	6/1940	T. F. from hot torn steel
B. & M.	532	112	Steelton	86205–E–4	6/1940	T. F. from hot torn steel

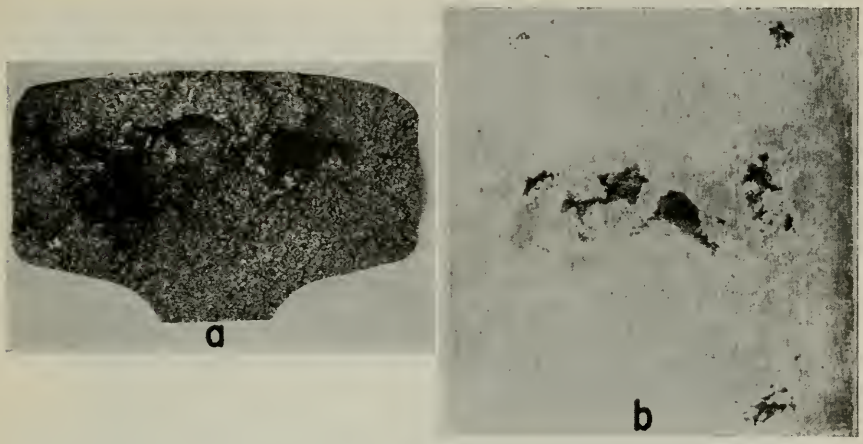

Fig. 1.—Transverse Fissure from Hot Torn Steel Laboratory Failed Rail No. 523.
(a) Rail with large holes located by detector car. There has been very little fatigue growth around the defects.
(b) Longitudinal slice cut from rail head showing other hot tears in the rail. Such defects are the result of the steel being too hot for successful rolling when the rail was rolled.

"hot torn steel" are standard mill terms for this defect, and it was recommended that they be used to indicate the cause of such rail failures. The objection to "porosity" is that this is a common mill term to indicate a porous condition of steel ingots and is the responsibility of the melting department. Hot tears are the responsibility of the rolling department.

A majority of the 20 rails which developed hot tears the past year were rolled before the cause of this defect was recognized in 1943. Table 3 lists the year of rolling of the 81 transverse and compound fissures from hot torn steel that have been found in control cooled rails.

Table 3.—Summary of Transverse Fissures from Hot Torn Steel

Year Rolled	*Transverse Fissures from Hot Torn Steel*
1935	2
1936	21
1937	10
1938	11
1939	8
1940	8
1941	8
1942	5
1943	6
1944	1
1945	1
Total	81

It will be noted that only two failures have occurred from this type of defect in rails manufactured since their cause was recognized. It should also be stated that 77 of the total number were rolled by two mills and the three mills that do not reheat their blooms have had no failures from this cause.

Most of the 12 detail fractures from shelling had been classified as transverse fissures. These failures are discussed in the report on shelly rail studies. The head and web separations from corrosion occurred in insulated joints. One vertical split head originated in an oxide inclusion from the bottom rail of an ingot which had not been cropped back sufficiently. There was one transverse fissure from shatter cracks in a rail rolled in 1938 before the mill had suitable covers for its cooling containers.

The fact that so few transverse fissure failures have been discovered in more than 8 million tons of control cooled rails rolled between 1935 and 1944 is certainly a demonstration of the improvement effected since control cooling was developed.

Failed End-Hardened Rails

Fig. 2 shows a failed end-hardened rail which developed a weeping crack on the end after slotting the joint with an emery wheel. Such failures are due to heat checks produced by the heat from the grinding wheels and occur quite frequently on rails which were quenched with water. Brinell and Rockwell hardness tests indicate that the rail end shown in Fig. 2 had a Brinell hardness above 400. Such hard rails are very likely to heat check on the ends during grinding unless a special soft abrasive wheel is used. It is because of this type of failure that the use of water for quenching rail ends in end hardening is not recommended.

Failed Rails Built Up By Welding

Two failed non-control cooled rails were examined which had been built up by arc welding for a distance of 18 in. from the rail end. Fig. 3 (a) shows the detail fracture which developed in this rail. Fig. 3 (b) is an etched cross section of the rail head

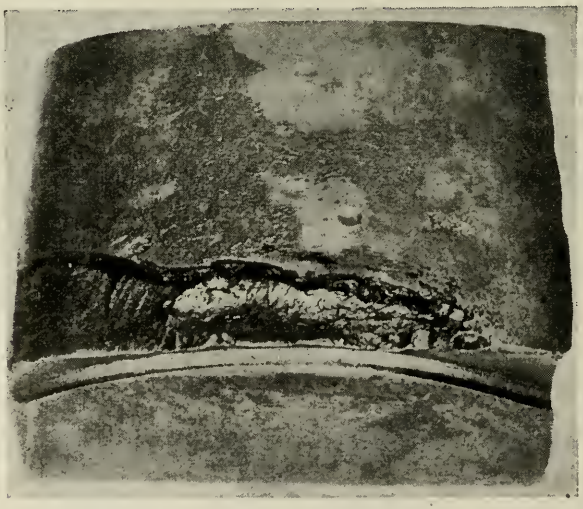

Fig. 2.—Failed End-Hardened Rail.

This rail end has been slotted by grinding. It was over 400 Brinell hard, which causes heat checks to develop on the ground surface. These heat checks develop into weeping cracks due to the pounding of car wheels.

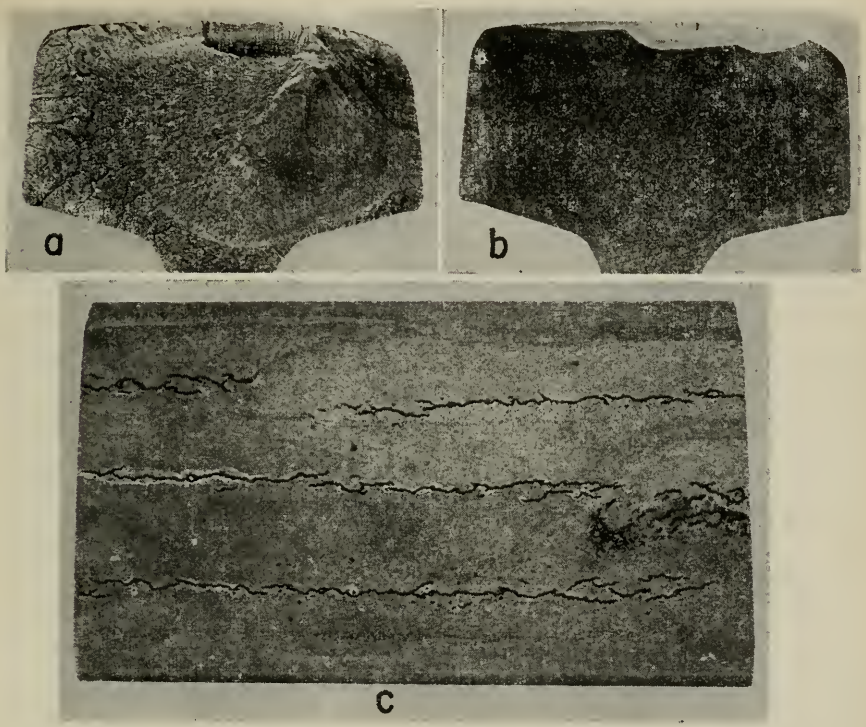

Fig. 3.—Detail Fracture from Arc Welding.
Lab. failed rail No. 493.
Arc welding was used to build up rail at low joint.
(a) Detail fracture covering most of rail head.
(b) Etched cross section of rail near fracture shows metal deposited by arc welding.
(c) Etched thread of rail showing cracks in metal deposited by arc welding.

showing the weld deposited metal. Fig. 3 (c) shows the tread of the rail after etching in acid to reveal shrinkage cracks in the weld deposited metal. Such cracks can be expected to develop in weld metal deposited on a cold rail by the arc welding process. If the arc welding is preceded by sufficient preheating of the rail and followed by post heating or slow cooling, it is possible to prevent such shrinkage cracks.

Twelve other failed non-control cooled rails were examined and reported to the railroad engineers supplying the specimens. The only unusual rail in this group was a bessemer rail which developed several transverse fissures from heavy segregation streaks. This rail had been rerolled and laid in track in 1913.

Report of Committee 1—Roadway and Ballast

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A. A. Winter
Edward Wise, Jr.
Committee

* Died July 2, 1947.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Physical properties of earth materials:

   (a) Roadbed. Load capacity. Relation to ballast. Allowable pressures. Progress report, presented as information ..... page 499

3. Natural waterways: Prevention of erosion.

   No report.

4. Culverts:

   (a) Wood culverts.
   Progress report, presented as information ..... page 507

   (b) Conditions requiring head walls, wing walls, inverts and aprons and requisites therefor.

   No report.

5. Roadway drainage: Adherence to recommended practice.

   Progress report, presented as information ..... page 508

6. Roadway protection:

   (a) Stabilization of roadbed by grouting: Describe methods used.

   Third progress report of the investigation of methods of roadbed stabilization ..... page 508

(b) Construction and protection of roadbed across reservoir areas; specifications.

Progress report, presented as information ..... page 530

(c) Chemical eradication of grass and weeds.

No report.

7. Tunnels: Construction and maintenance.

No report.

8. Fences:

(a) Corrosion-resisting fence wire, collaborating with appropriate subcommittee of Committee A-5 on Corrosion of Iron and Steel, ASTM.

No report.

(b) Electric shock fences and their adaptability to railroad requirements, collaborating with the Electrical Section, Engineering Division, AAR.

No report.

(c) Importance of periodical fence inspection.

No report.

9. Signs.

No report.

10. Ballast:

(a) Tests.

No report.

(b) Ballasting practices.

No report.

(c) Special ballasts.

No report.

The Committee on Roadway and Ballast,
W. C. Swartout, *Chairman*.

Littleton Hewitt Roden

The Committee on Roadway and Ballast records with sorrow the death on July 2, 1947, of its vice-chairman, Littleton Hewitt Roden. He contributed generously of his time and efforts to the work of the committee.

Reference is made to the memoir offered in the report of the Committee on Track on page 324.

Report on Assignment 2

Physical Properties of Earth Materials

(a) Roadbed. Load Capacity. Relation to Ballast. Allowable Pressures

H. W. Legro (chairman, subcommittee), W. J. Cable, J. C. DeJarnette, Jr., J. W. Demcoe, Albert Haertlein, F. W. Hillman, L. H. Jentoft, J. W. Poulter, C. S. Robinson, R. G. Scott, A. A. Winter.

This is a preliminary report on the use of soil pressure cells with electrical recording equipment for the measurement of pressures in railroad subgrades under moving loads. These tests were conducted, under the general direction of G. M. Magee, re-

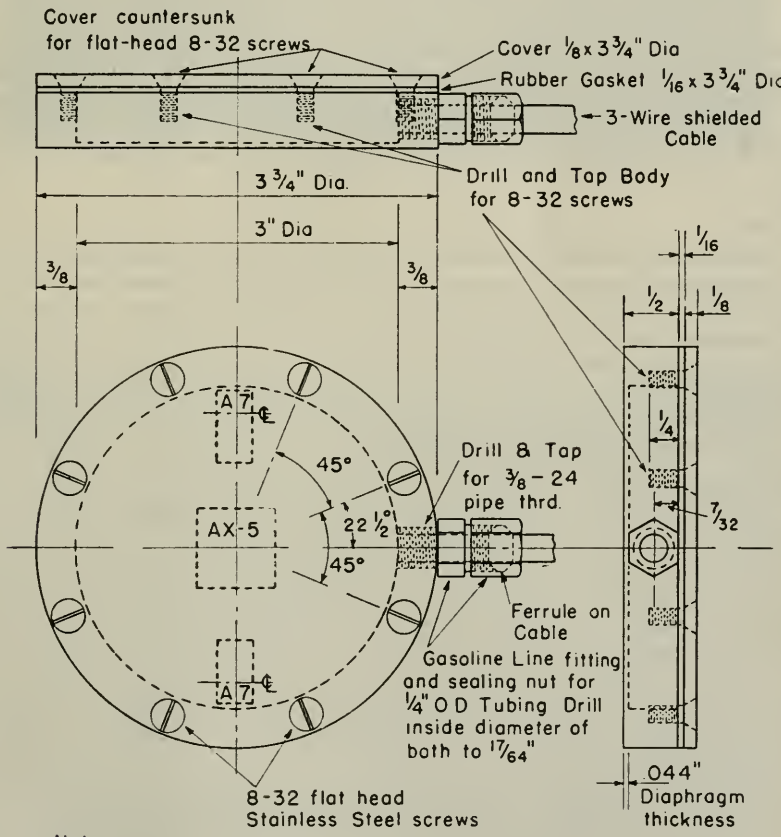

Cover countersunk for flat-head 8-32 screws
Cover 1/8 x 3 3/4" Dia
Rubber Gasket 1/16 x 3 3/4" Dia.
3-Wire shielded Cable
3 3/4" Dia.
Drill and Tap Body for 8-32 screws
3" Dia
3/8
3/8
1/16
1/2
1/8
1/4
7/32
A-7
45°
AX-5
22 1/2°
45°
A-7
Drill & Tap for 3/8 - 24 pipe thrd.
Ferrule on Cable
Gasoline Line fitting and sealing nut for 1/4" O D Tubing Drill inside diameter of both to 17/64"
8-32 flat head Stainless Steel screws
044" Diaphragm thickness
Note
Body and Cover made of Stainless Steel
Goges AX-5 and A-7 shown in outline only and are to be cemented to inside face of diaphragm

Fig. 1.—Details of AAR Soil Pressure Cell.

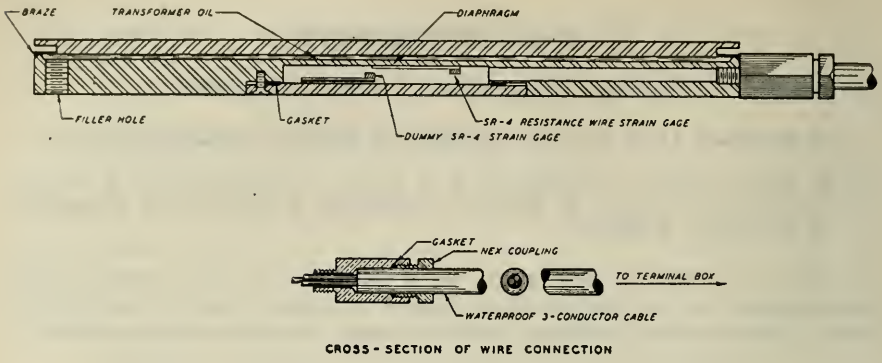


Fig. 2.—U. S. Waterways Experiment Station Soil Pressure Cell.

search engineer, by Randon Ferguson, electrical engineer, M. F. Smucker, assistant electrical engineer, C. G. Keith, test assistant, and Rockwell Smith, roadway engineer of the research staff of the Engineering Division of the Association of American Railroads upon the recommendation of the Roadway and Ballast Committee of the AREA. All tests were run on the Chicago & North Western tracks near Harvard, Ill., during July and August 1947.

Purpose

Theoretically, pressures in soils may be computed, but these computations are based on assumptions of the elastic properties of soils. It is to check the theory and to develop information on vertical and lateral stresses in soils that the pressure cell tests have been instituted. The work in 1947 was concerned only with the trial of several types of cells and the methods of installation to determine from which the best results may be expected.

It is hoped that eventually data can be obtained on horizontal and vertical stresses in railroad subgrades before and after grouting.

Soil Pressure Cells

Three cells of different construction were used in this installation. A general description follows:

1. *The AAR cell.*—The details are shown in Fig. 1. Essentially the cell consists of a steel diaphragm to which are attached four SR-4 wire strain gages. The strain gage noted as AX-5 on the figure is a 90-deg. double gage. Under load the two outside gages are in compression and the double center gage is in tension. The circuit is so wired that the output of the gages complement each other and give the pressure cell greater sensitivity than would otherwise be possible with the thickness of diaphragm used. This cell was developed and made by the research staff of the AAR. Fig. 3 is a view of the interior of the cell.

2. *Waterways Experiment Station Cell.* Fig. 2 shows the general features of the U. S. Waterways Experiment Station cell, identified as the WES cell. It was first developed by Dr. J. O. Osterberg of Northwestern University. The cell used in these tests was obtained through the courtesy of the Baldwin Locomotive Works which has the patent rights for the manufacture. It consists of an inner diaphragm separated by an oil chamber from the outer bearing plate. In these tests a bronze cell 3 in. in diameter was used with four active strain gages hooked up in the same manner as the AAR cell. Fig. 4 is a photo of the cell used.

Fig. 3.—AAR Cell Showing Strain Gage Hook Up.

Fig. 4.—Waterways Experiment Station Pressure Cell.

Fig. 5.—Poulter 6-in. Soil Pressure Cell.

Fig. 6.—Calibration Equipment for Soil Pressure Cells.

Fig. 7.—Trench and Auger Holes for Cell Installation.

3. *Poulter Cells.* Two cells, 6 in. and 4 in. in diameter were developed and made by J. W. Poulter, research engineer of the Koehring Co. and a member of this committee. Fig. 5 shows the 6 in. cell. These cells identified as P gages, also contain a hydraulic chamber between two thin brass diaphragms. The pressure to be recorded is transmitted through to the inner diaphragm which has point bearing on a brass beam. Wire gages are attached to the beam, two on the 6 in. cell measuring tension and four on the 4 in. cell, measuring both compression and tension in the beam and so circuited that all gages increment the others which results in greater sensitivity. In the Poulter cells the diaphragms are thin enough to act as membranes.

The cells were all used with amplifiers and oscillographic equipment that recorded the pressures photographically. This equipment is the same as that used to record loads under moving traffic for bridge members, rail, etc., and prior to the pressure cell tests it had been used at the same location to record various stresses in rail under wheels with flat spots.

Calibration

The cells were all calibrated in an air chamber. Fig. 6 shows the equipment and the method adopted. In addition, several of the cells were given a check calibration under a layer of soil with the air applied to the soil. All cells showed a straight line calibration. Pressure was applied in increments and the resulting deflection of the gal-

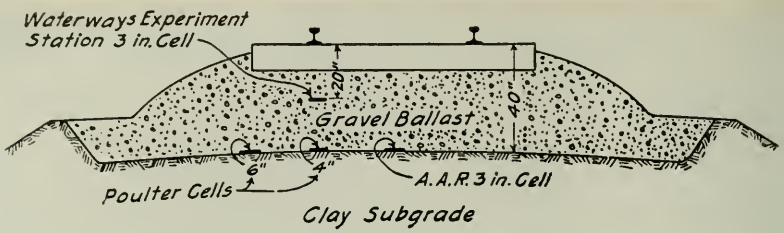


Fig. 8.—Location of Soil Pressure Cells.

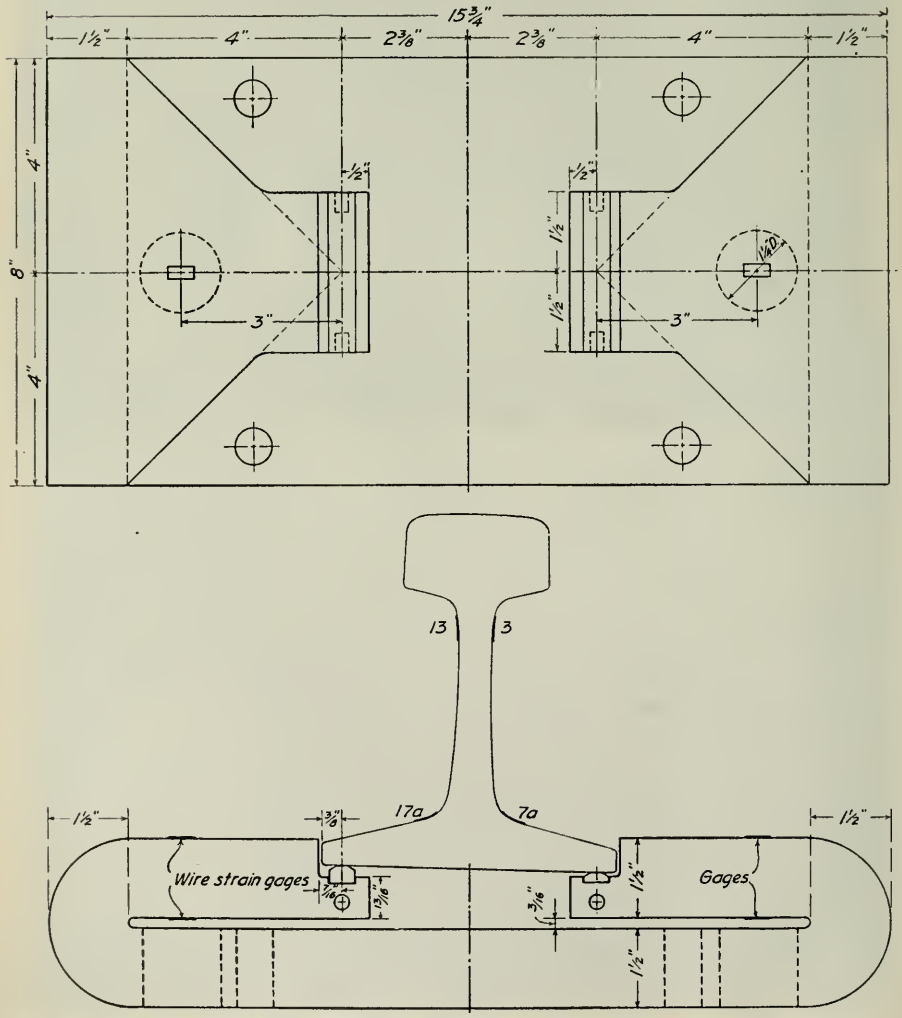


Fig. 9.—Dynamometer Tie Plate for Determining Pressure on Ties.

vanometer trace noted. The calibration pressure exceeded the expected pressure in service and this pressure was doubled and maintained for several minutes as a check to determine the sealing of the cells and the connections. Any leak in the cells would cause an immediate decrease in the deflection of the oscillographic trace. During the actual test runs the sensitivity of the oscillograph was changed as conditions demanded, necessitating a second calibration after the cells were removed from the subgrade.

Installation

The first installation of the cells was made by digging through the ballast at the end of the tie and tunneling horizontally with a soil auger. The cells were installed in the auger holes at a position directly under the rail. Clay soil similar to that in the subgrade was compacted over the cell. Fig. 7 shows the installation arrangement for two cells 15 in. apart. These cells were placed 46 in. below base of rail. The other two cells were placed similarly at a 42-in. depth but were spaced 7 ft. apart. Test runs 1 to 29 were made with this installation.

The second installation of the same cells was made in an open trench excavated through the track. This trench was 2½ ft. wide on the bottom and was cut through the ballast and 2 in. into the subgrade. The bottom of each cell was 40 in. below base of rail except one cell, placed 20 in. below the base of rail in the ballast. The three cells in the bottom of the trench were covered with clay soil, hand packed, to a depth of 1 in. The trench was backfilled with gravel ballast in 6-in. layers, thoroughly tamped. Fig. 8 shows the location of the cells in the track. Test runs 30 to 57 were made with this installation.

In addition to the pressure cells, wire gages were attached to the rail for runs 12 to 31. These gages indicated the wheel position and recorded the stress in the rail directly over a pressure cell. For runs 35 to 57, dynamometer tie plates were installed on the tie over the cells. These are specially constructed cantilever plates with wire strain gages that produced records by means of the oscillograph from which the actual load on the tie may be calculated. Through this the pressure cell readings can be compared to the actual load on the tie. Fig. 9 shows the details of the dynamometer tie plates developed by the Engineering Division research staff.

Discussion

Two cells installed in the auger holes under the rail remained in place for 28 days. Two others similarly installed remained in place for 8 days. A total of 29 runs was recorded. All the cells registered but the indicated pressures were only 20 to 40 percent of the theoretical pressures calculated for the cell position. Evidently the arching action of the soil and ballast was still effective after the 28 days. There was little or no increase in recorded pressure with time.

The second installation in the open trench remained in place for 20 days and 28 runs were recorded. The indicated soil pressures increased with time and the values approached and exceeded theoretical pressures. After every run it was necessary to tamp up the tie over the trench. Some of the records indicated that the first loads depressed the tie because of subsidence of the backfill so that little or no load was recorded on either the dynamometer tie plates or the pressure cells. This condition improved with time, as shown in the records of the later runs. Fig. 10 shows run No. 42 with the pressures indicated by the pressure cells and tie plates. The effect of impact can be noticed.

Conclusion

The results obtained indicate that the cells used can all be adapted to the measurement of subgrade soil pressures. In the last ten runs the Waterways cell became very

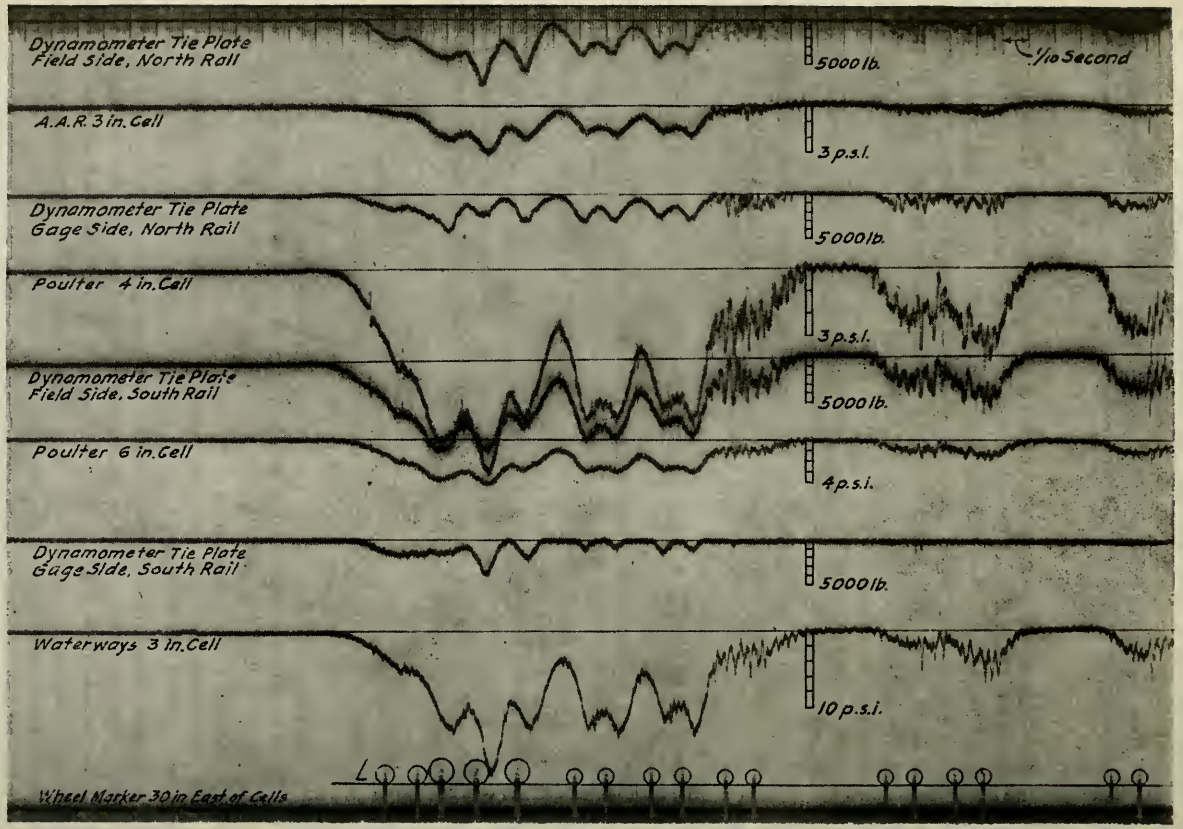
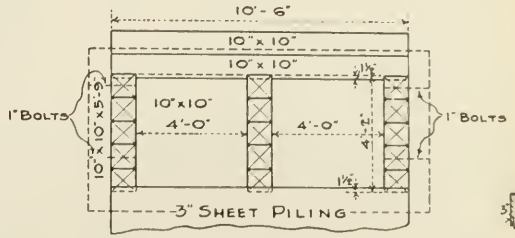


Fig. 10.—Run No. 42. Locomotive 236 (4–6–0). 35 mph.

1"B
1"Bol

NOTE: SIDE BLOCKS, AS SHOWN IN DOTTED LINES TO BE USED IN SAND EMBANKMENTS, AT 10 OR 12 FT. CENTERS AND SECURED WITH 1" BOLTS



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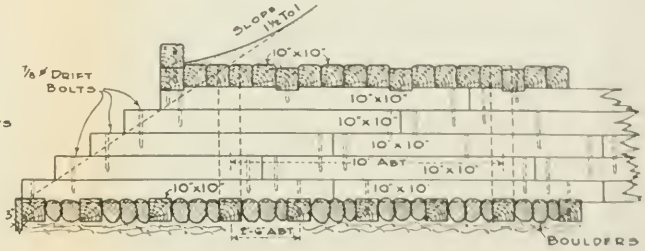
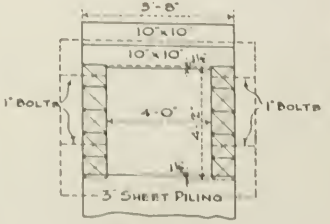
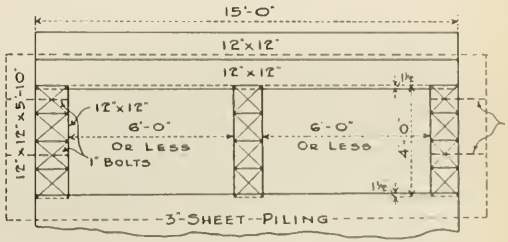


4'x4' BOX CULVERT



SINGLE



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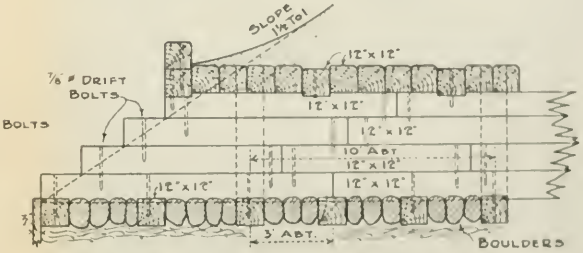
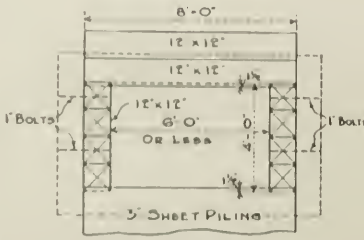
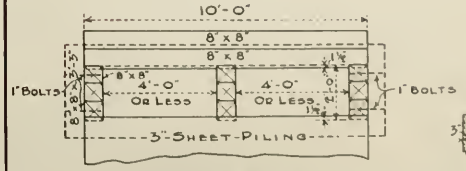


6'x4' BOX CULVERT



SINGLE

NOTE: WOOD CULVERTS WILL BE AUTHORIZED ONLY WHERE METAL, CLAY OR CONCRETE CULVERTS CANNOT BE PLACED ECONOMICALLY.



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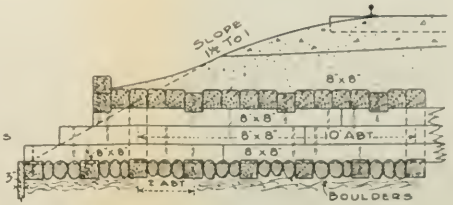
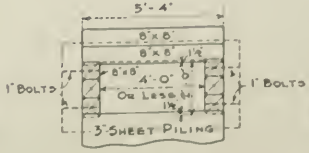


4'x2' BOX CULVERT



SINGLE

WOOD CULVERTS

MAY 1947

sensitive and gave readings greatly above the probable values. Upon removal of this cell from the subgrade it appeared there was a partial failure in the electrical connections. Only pressures under load were recorded. The cells were rebalanced before each run which eliminated the effect of temperature and dead load on the wire strain gages. The AAR cell which is simplest in construction gave results as consistent as the more elaborate cells.

No analysis of the accuracy of the cells has been made but the indicated pressure appears proportional to the load on the tie as determined by the dynamometer tie plates. The data indicate that additional tests especially for horizontal pressures, may be of value.

The manner of installation has considerable effect on the action of the pressure cells. The need for an open trench is indicated and the wider the trench the sooner the gages will register full pressure. but in any case a considerable time should be permitted for the backfill of the trench to adjust itself. The bearing of the tie also affects the indicated pressures greatly.

These tests afford no more than an approximate evaluation of the effect of impact on soil pressures, although they demonstrate that considerable impact effect is present.

Report on Assignment 4 (a)

Wood Culverts

G. W. Miller (chairman, subcommittee), W. T. Adams, F. W. Biltz, A. J. Boase, L. H. Bond, W. J. Cable, T. F. de Capiteau, H. W. Johnston, J. A. Noble, R. G. Scott, H. M. Tremaine, H. P. Pickering, A. A. Winter.

Your committee submits the following progress report as information including a tentative plan on wood box culverts, and requests comments and criticisms thereon.

Under this assignment, one preliminary plan dated May 1947, showing several types of wood culverts is presented. This drawing was developed after a study of various types of wood culverts used by a number of railroads. It represents the type of culvert that can be built from local timber at relatively low cost when a new line is under construction.

During the war years, it was necessary to develop plans for timber culverts owing to a scarcity of metal and other types of culverts. This emergency has now passed and your committee considers that more permanent types of culverts should now be used except in the construction of temporary trackage or new construction where it is desirable and necessary to keep the cost of such construction as low as possible.

Wood culverts are not recommended where pipe or other types of more permanent construction are available at lower cost. Where wood culverts are used, all brush and rubbish which may tend to increase the fire hazard must be kept clear of the inlet and outlet.

Other types of wood culverts used during the war years when metal and reinforcing materials were scarce include:

(1) Laminated timber culverts.
(2) Circular stave pipes, treated and untreated.
(3) Squared timber, usually treated with creosote.

The continued use of timber culverts depends primarily on the availability of such timber, the cost of other materials and the economic life that may be obtained from each type in the locality where it will be used.

Report on Assignment 5

Roadway Drainage: Adherence to Recommended Practice

H. S. Ashley (chairman, subcommittee), Blair Blowers, Clifton Brannon, J. E. Chubb, L. B. Craig, H. L. Exley, H. G. Johnson, L. R. Lamport, Paul McKay, H. P. Pickering, R. G. Scott, H. M. Tremaine.

This report is presented as information.

For the purpose of a further check on adherence to recommended practice for roadway drainage, your committee submitted a questionnaire to officers of 25 railroads of whom 21 provided replies. A study of these replies revealed very little change in practice from that disclosed as the result of inquiries made by the committee in 1942 and reported in the Proceedings, Vol. 44, 1943, page 513.

Report on Assignment 6 (a)

Stabilization of Roadbed by Grouting: Describe Methods Used

F. H. Simpson (chairman, subcommittee), W. T. Adams, T. A. Blair, A. J. Boase, L. H Bond, J. P. Datesman, T. F. de Capiteau, J. C. DeJarnette, Jr., G. W. Payne, H. P. Pickering, J. W. Poulter, C. S. Robinson, A. A. Winter.

The investigation of this assignment has been handled for the committee by the Engineering Division research staff as a part of the research program of the Association of American Railroads. This year at the committee's suggestion, the investigation has been extended to cover briefly the stabilization of the roadway by means of pole and tie driving and sand filled spud holes, in addition to further consideration of pressure grouting, particularly with respect to the grouting of slides.

Third Progress Report of the Investigation of Methods of Roadbed Stabilization

Introduction

This is the third progress report of an investigation begun in 1945 to study the methods and results of various types of roadbed stabilization. The first two reports appear in the Proceedings, Vols. 47, 1946 and 48, 1947. These reports were limited to methods of pressure grouting. This year's report includes, in addition, brief discussions of several other types of stabilization, i.e., tie and pole driving and sand piles.

This investigation has been conducted under a cooperative agreement between the Engineering Experiment Station of the University of Illinois and the Association of American Railroads under the general direction of G. M. Magee, research engineer of the Engineering Division, AAR, and Dr. R. B. Peck, research professor of soil mechanics of the university. Rockwell Smith, roadway engineer of the Engineering Division research staff handled the field work and prepared this report. Soil tests were made at the experiment station under the direction of Dr. T. H. Thornburn of the university staff.

TABLE [illegible] ... [illegible] ... DATA

Railroad and Location	Year	Length of Section Reported	Grout Acceptance cu.ft. per tr.ft.	Grout & stone cu. ft. Cement	Sand	Fly-ash	Talc	Character of Track Ballast Type & Type of Insp. Last Lift & Fill	Cost of Grout per cu. ft.		Maintenance Data Before Grouting	Maintenance Data After Grouting	Period of Record Before	Period of Record After	Remarks Grouting Equipment & Type of Work
									$						
ATSF															
Near Olathe, Ks.	1945	-	-	1-1	12-6	-	1.2	Limestone, slides & soft track	-	-	-	-	-	-	
Near Alvie, Tex.	1945	5,661	1.49	1	12	-	.75	Shale, 6' fill, soft track	1.78	.46	-	-	-	-	Hydraulic, track only
Near Snyder, Tex.	1946	-	-	1	32	1	3.[illegible]	Cr. stone & screenings 1' cut & fill, soft track (Pe[illegible]ast pockets.	-	-	-	-	-	-	" " "
Near Brenham, Tex.	1947	1,867	35.[illegible]4	1	16	1	1.0	Gravel-Cinders, slides 50' fill	8.89	.22	-	-	-	-	" track & fill
B&O															
North Baltimore, O.	1946	6,274	2.50	1	10	-	-	Crushed stone, [illegible]queezes, pockets, cinders	.76	0.30	3,678 hrs.	1,760 hrs.	9 mo.	8 mo.	Hydraulic, track only
Van Sibber, Md.	1946	6,917	9.02	1	14	-	-	- - unstable fill, soft track	4.46	.48	8,829 hrs.	2,884 hrs.	9 mo.	9 mo.	" " track & fill
E. St. Louis, Ill.	1947	7,562	5.76	1	6	-	-	- - - [illegible]' fill	.31	.40	-	-	-	-	" " "
CB&Q															
Near Quincy, Ill.	1946	16,676	1.68	1	7	-	.67	Gravel, soft track, [illegible]ve cuts & fills	.91	.43	$6,224.73	$4,[illegible]34.86	1 yr.	1 yr.	Hydraulic, track only
Near Ardmore, S. D.	1946	3,870	7.85	1	6	-	-	Crushed stone, soft trace, unstable fills	2.0	.86	1,534.08	934.77	1 yr.	1 yr.	" " track & fill
Near Beardstown, Ill.	1946	269	14.59	1	3	.5	.5	Cinders, sliding 50' fill	4.12	0.42	2,107.29	[illegible].0	9 mo.	9 mo.	" " "
" " "	1947	2,220	7.93	1	7	0.5	1.0	Gravel, - 40' fill	-	-	-	-	-	-	" " "
Near Fairfield, Ia.	1947	2,500 (approx)	-	1	7	.0	-	Gravel & cinders, sliding 20' fill	-	-	-	-	-	-	" " "
Near Ottumwa, Ia.	1947	2,500 "	-	1	7	.5	.67	Sling & " - 70' fi.l	-	-	-	-	-	-	" " "
C&NW															
Near Mondamin, Ia.	1945	-	4.2	1	7	-	1.0	Cinders, unstable 7' fill	1.89	.39	-	-	-	-	Hydraulic, track only
Near Council Bluffs, Ia.	1946	12,500 (approx)	4.1	1	7	-	1.0	Crushed stone, gravel, cinders, unstable 1' fill	1.89	.44	2,[illegible]63 hrs.	448 hrs.	8 mo.	8 mo.	Hydraulic & pneumatic, (track only, welded rail
Near Clinton, Ia.	1946	325 "	27.9	1	3	-	.5	Crushed stone & cinders, sliding 30' fill	14.08	.43	-	-	-	-	Hydraulic, track & fill
Near Salix, Ia.	1947	6,500 "	4.0	1	7	-	1.6	Cinders, soft track, unstable 4' fills	-	-	-	-	-	-	" " "
CMSt.P&P															
Near Owego, Ia.	1945	15,297	1.65	1	4	-	-	Gravel, [illegible]inders, pockets, soft trace, 6' fill	1.34	0.63	$5,870.00	$ [illegible],[illegible]0.00	1 yr.	1 yr.	[illegible]ontract pneumatic, trace
CP&P															
Mercer-Princeton, Mo.	1945	14,095	3.16	1	6	-	-	Grat & mine waste, soft trace, cuts & fills	[illegible].79	0.86	(100%) [illegible]	(80%) (100%)	2 yr.	2 yr.	(Hydraulic, variable meint (cost[illegible]
D&RGW															
Near Gilt, Colo.	1946	900	2.64	1	10	-	.75	Black Slag, unstable 1' fill	-	-	(per month) (439 hrs.)	(per month) (17.0 hrs.)	1 yr.	3 mo.	pneumatic, trace & fill
ILLINOIS CENTRAL															
Dobbs, Ill.-Tunnel No. 2	1945	3,216	1.90	1	0	-	-	Crushed rock, tunnel, mud boils	4.07	2.13	(per month) (514 hrs.)	(per month) (240 hrs.)	1 yr.	2[illegible] yr.	Hydraulic on trace equip.
Chicago Terminal	1944	80	13.9	1	4	1	-	Crushed rock, soft trace, [illegible]able slip section	8.42	2.61	weekly	2 mo	1 yr.	2 yr.	pneumatic, trace only
Carbondale Yards	1946	3,577	1.48	1	7	1	-	Cinders, squeezes, soft track	[illegible].36	0.76	(per month) (192 hrs.)	(per month) (24 hrs.)	1 yr.	1 yr.	Hydraulic, on trace equip.
Near Bluford, Ill.	1947	1,521	23.30		7		-	Crushed stone, cinders, sliding fill	8.18	2.38	-	-	-	-	Hydraulic, trace & fill
LITCHFIELD & MADISON															
Near Glen Carbon, Ill.	1947	4,214	6.04	1	6	1	-	Cinders, [illegible]e'olding & unstable fill	-	-	[illegible]4)	(84)	1 yr.	1 yr.	Hydraulic, trace only
LOUISVILLE & NASHVILLE															
Near Cullman, Ala.	1947	1,200	2.00	1	1	-	-	Crushed stone, cut 20' sandy cut	-	-	-	-	-	-	Hydraulic, trace only
MO, KAN, TEX.															
Morun-Savonburg, Kans.	1945	8,941	3.74	1	8	-	1.0	Chat, [illegible]ers & soft track, 10' cuts & fills	.48	.66	$5,870 est. (per month)	$1,404.13 (per month)	2 yr.	2 yr.	Contract Hydraulic, trace only
NEW YORK CENTRAL															
Near Welland, Ont.	1945	7,400	5.75	1	1	-	-	Crushed stone, pockets & soft trace, 10' fills	.83	0.47	$1,178.88	11.50	1 yr.	1 yr.	Pneumatic, spot work, trace only
Near Vermillion, O.	1945	937	3.15	1	1	-	-	Crushed stone, pockets & soft trace, 10' fills	2.54	1.81	37.60	.0	1 yr.	1 yr.	" " "
Sr. 222 Guilford, Ind.	1945	233	31.50	1	1	-	-	" " cinders, sliding 40' fill	18.06	7.67	338.31	2.60	1 yr.	1 yr.	" trace & fill
Near Millsboro, Ill.	1945	3,255	4.54	1	1	-	-	" " rough track, 25' fill	1.07	0.24	1,093.00	293.60	1 yr.	1 yr.	" trace only
Near Corunna, Ind.	1946	2,560	5.62	1	1	-	-	" " unstable 12' fill	2.98	0.53	221.88	6.0	1 yr.	1 yr.	" fill only, grout ltd.
W.P. 33 - 16 Welsburg, Ind.	1947	400	16.5	1	1	-	-	" " cinders, sliding 60' fill	-	-	-	-	-	-	Pneumatic, track & fill
PENNSYLVANIA															
Near Sedford, O.	(1946 & (1947)	6,416	5.02	1	1	2 Lime Ash	-	Crushed stone, soft track, 20' cut	2.64	0.53	-	Annual Saving $ 2,[illegible]16.00	1 yr.	? 40 lyr	Hydraulic, track only Includes 2,264 tr. ft. grouted below.

This year the investigation of the research staff of the Engineering Division, AAR, included an experimental installation of soil pressure gages in the clay soil under a track. This installation was principally to test the gages and methods of installation and no quantitative analysis can be made of the results. A description of the gages and installation is given as part of the report of subcommittee 2 (a), Physical Properties of Earth Materials.

Grouting equipment and procedures have remained very similar to those of 1946. Additional roads have adopted the method for certain stabilization problems and in general the roads that have engaged in this work have continued to do so, many on an increased scale. It is felt that the descriptions of the equipment, mixtures, and detailed grouting practices in two previous reports will suffice until improved or especially interesting techniques are developed. It is also felt that further progress in stabilization of soft spots by grouting or any other procedure cannot be made without more basic data concerning the causes and nature of soft spot development. The data can best be obtained under controlled conditions. Accordingly, a large-scale repeated-load machine has been designed and is nearing completion at the University of Illinois. By means of this machine, various types of ballast and subgrades can be subjected to conditions simulating the effect of traffic in the field, and their performance under different conditions of moisture can be observed.

Numerous tests were made in the field on the flow characteristics of the slurry used in the grouting operations. A funnel-shaped cast aluminum flow cone of 221 cu. in. capacity was used. It was thought that the time required to discharge this quantity of grout through a ½ in. orifice at the apex of the cone would indicate flow characteristics of various mixtures of cement, sand, flyash, asphalt, and water, and would tend to indicate an optimum quantity for the various materials. This has been found to be true for thicker grouts such as might be used for cement-bound macadam. For stabilization of subgrades, however, where the voids are usually small and the grout must be forced through hose lines and injection points, little or no difference was found in the time of flow for various grouts that fulfilled practical requirements. From these tests no conclusions could be drawn as to the effect of various admixtures. It appears that their value lies chiefly in their lubrication characteristics and in their effect in holding particles in suspension. Determination of these qualities would be a laboratory study of some magnitude and it is doubtful that the results would be of any great practical value. Present field practice on various roads is uniform in the use of 4 to 5 gal. of water per cu. ft. of loose dry material and if used at all, of approximately 0.1 gal. of asphalt emulsion.

For the purpose of this and preceding reports the quantity of grout accepted has been computed as the sum of the loose volumes of the dry ingredients. The absolute volume of all the ingredients will run up to 20 percent greater. Refinements in reporting the proportions comprising a slurry would be at variance with field practice. The standard 94-lb. bag of portland cement is assumed as 1 cu. ft. and this is the basis for proportioning. In actual practice however, the various materials often are proportioned by shovels and the water is added by the operator to produce the consistency of grout desired. The quantities may vary up to 20 percent of the established batch units. Experience indicates that, for deep grouting especially, the variation in the proportions of a grout within the range of mixtures indicated in this report will have little effect on the results obtained.

Table 1 gives the available information on all the grouting projects observed in the course of this investigation. For a number of 1945 and 1946 jobs the data include the maintenance record both before and after grouting. As far as the limited time of

record can be accepted this showing is very favorable. It is planned to keep this record up to date and also to inspect and obtain data on grouting projects completed before the initiation of this investigation.

A most interesting development in pressure grouting on roadways is the adaptation of the process to sliding or slumping fills. Fills as high as 80 ft. have been treated. A number of these fill stabilization jobs are discussed briefly and are also included in the tabulation. On most of this heavy work hydraulic equipment has been used but the pneumatic process with its relatively light-weight equipment has also been successfully adapted. With the exception of one project, described last year, the grouting was designed to inject all the grout possible into the fills. Acceptance over some sections as short as one or two rail lengths has run as high as 100 cu. ft. per track foot, and there is a record of one fill 1800 ft. in length and a maximum of 50 feet in height where the acceptance averaged over 35 cu. ft. per track foot.

While there is not complete agreement as yet that the heavy grouting work required to stabilize a fill will return as much maintenance saving as out-of-face grouting of soft track and ballast pockets, the removal of slow orders and potential hazards to traffic have, for some roads, shifted the balance in favor of unstable fill grouting. The following gives in some detail conditions encountered on the fills of five railroads.

Santa Fe

Fig. 1 pictures a fill on the Atchison, Topeka & Santa Fe Railway near Brenham, Tex., on which grouting was completed during February 1947. This fill has required high maintenance for years. A profile is shown in Fig. 2. Drains and piling have been installed in efforts to control the slides and reduce costs. These installations have proved beneficial but not permanent. The fill has a maximum height of about 50 ft., and is built across a valley with a floor that slopes downward very slightly to the south. A number of slips and slides have occurred on the high side as well as on the downstream side. These slides and slips are of various types. They have affected the slopes, and in several sections the natural ground immediately adjacent to the fill. The soils are clays from adjacent cuts. They are extremely wet where squeezes occur. Because of property encroachment the fill has to be maintained to the original section on part of the south side. This side has pile bulkheads which are showing considerable strain.

In the present grouting program, a gridwork was laid out on the entire fill. Injection points were located at each point of intersection starting at the bottom of the fill. As many as five injections were made on each side of the fill at a single cross section.

The grouting covered 1867 track feet; 65,609 cu. ft. of grout were injected for an average of 35.14 cu. ft. per track foot. As the grouting was extended well into stable track the average acceptance on the fill proper was considerably higher and on several days the acceptance was over 100 cu. ft. per track foot.

The grout mix consisted of 1 cu. ft. cement, 16 cu. ft. sand, 1 cu. ft. fly-ash, 1 gal. asphalt emulsion, and water as required, approximately 70 gal. It was pumped by a mud-jack.

While no record is yet available as to maintenance savings effected, the grouting has been very successful in reducing labor requirements for routine maintenance, according to supervisory officers. A record is being kept and will be available.

Burlington

Grouting on the Chicago, Burlington & Quincy Railroad between Beardstown and Vermont, Ill. is described in last year's report in the Proceedings, Vol. 48, 1947, page

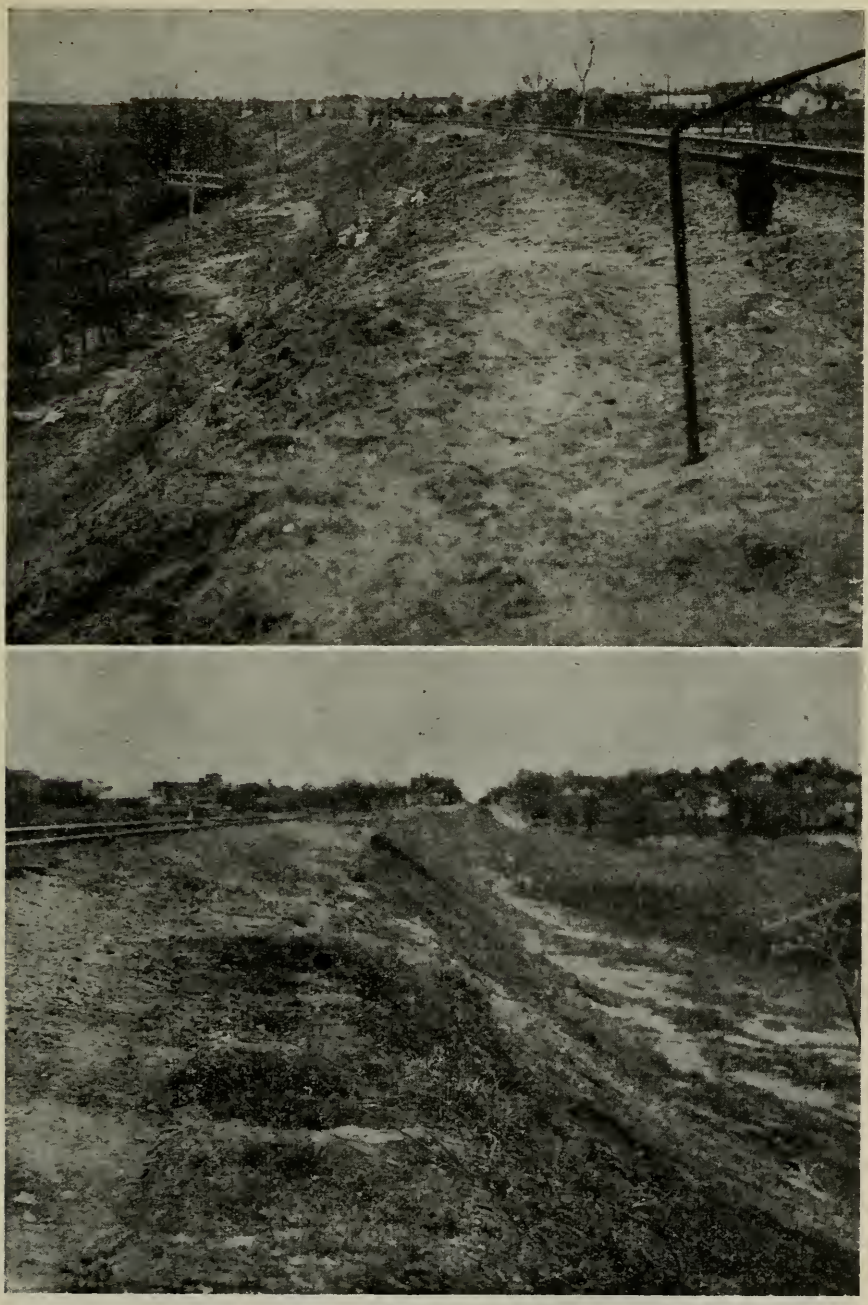


Fig. 1.—Santa Fe Fill near Brenham, Tex.

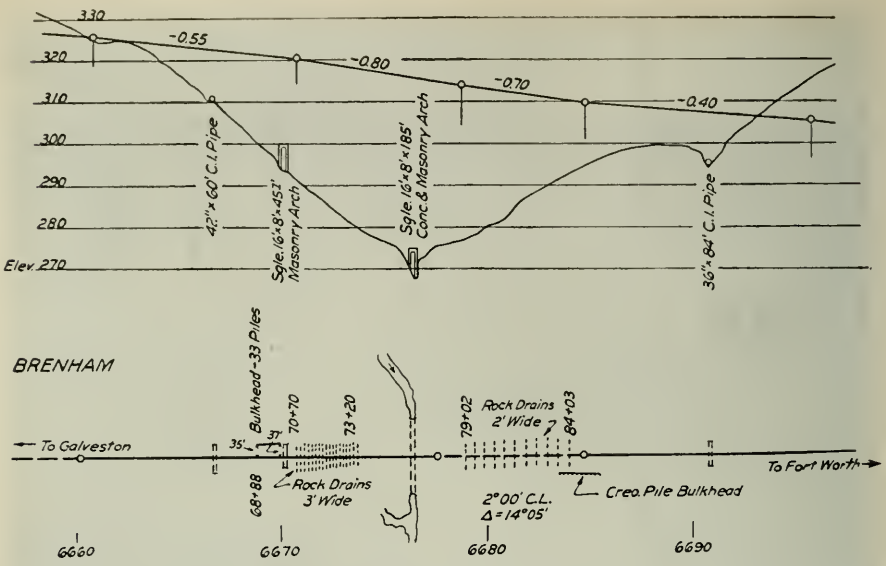


Fig. 2.—Santa Fe, Profile of Fill near Brenham, Tex.

Fig. 3.—Burlington Fill at M. P. 130 near Beardstown, Ill.

Fig. 4.—Burlington Fill at M. P. 130. Note Seepage from Fill.

512. Two fills grouted in 1946 on this line have required practically no track or shoulder maintenance since grouting. The maintenance cost record of one fill is given in the tabulation and shows a saving of $2,107.28. This record pertains to a year when rainfall has been severe and other fills in the vicinity have shown the effects of the adverse moisture conditions by a number of slips and slides of more serious proportions than usual. The fills for the 1946 work were selected first for stabilization because they appeared to be among the most critical. The results obtained to date on these fills, compared to similar fills not grouted, have been very favorable and have led to the extension of grouting to other locations on the line, one of which is described below.

The fill at M. P. 130 is approximately 40 feet high on the west and 25 feet on the east. A section extending 200 feet both north and south of the mile post was seriously affected by sliding this year, and has shown a tendency to slide for a number of years. The west slope slipped appreciably and required considerable material to restore the fill to the original width. The lower 15 or 20 ft. of the fill, consisting of very wet and highly plastic clay, flowed out and down. Before grouting, this material was bulldozed out to a uniform slope about 3 to 1 and the upper portion of the fill restored to a steeper slope with gravel. See Fig. 3. Downward movement of the fill was continuing slowly at the time grouting was started. Water seeped from the fill after the movement had occurred, mostly at the top of the squeeze. The flow accelerated considerably during the grouting, after which water seeped for a period exceeding two months. Fig. 4.

A total of 2220 continuous track feet was grouted. This included the fill discussed above and an adjacent cut and fill. A total of 17604 cu. ft. was injected, an average of 7.9 cu. ft. per track foot. Grout acceptance through the slide section proper averaged over 30 cu. ft. per track foot.

Injections were made on the slopes at vertical intervals of about 5 ft. and horizontal intervals of about 6 ft. The mix was 1 cu. ft. cement, 7 cu. ft. sand, ½ cu. ft.

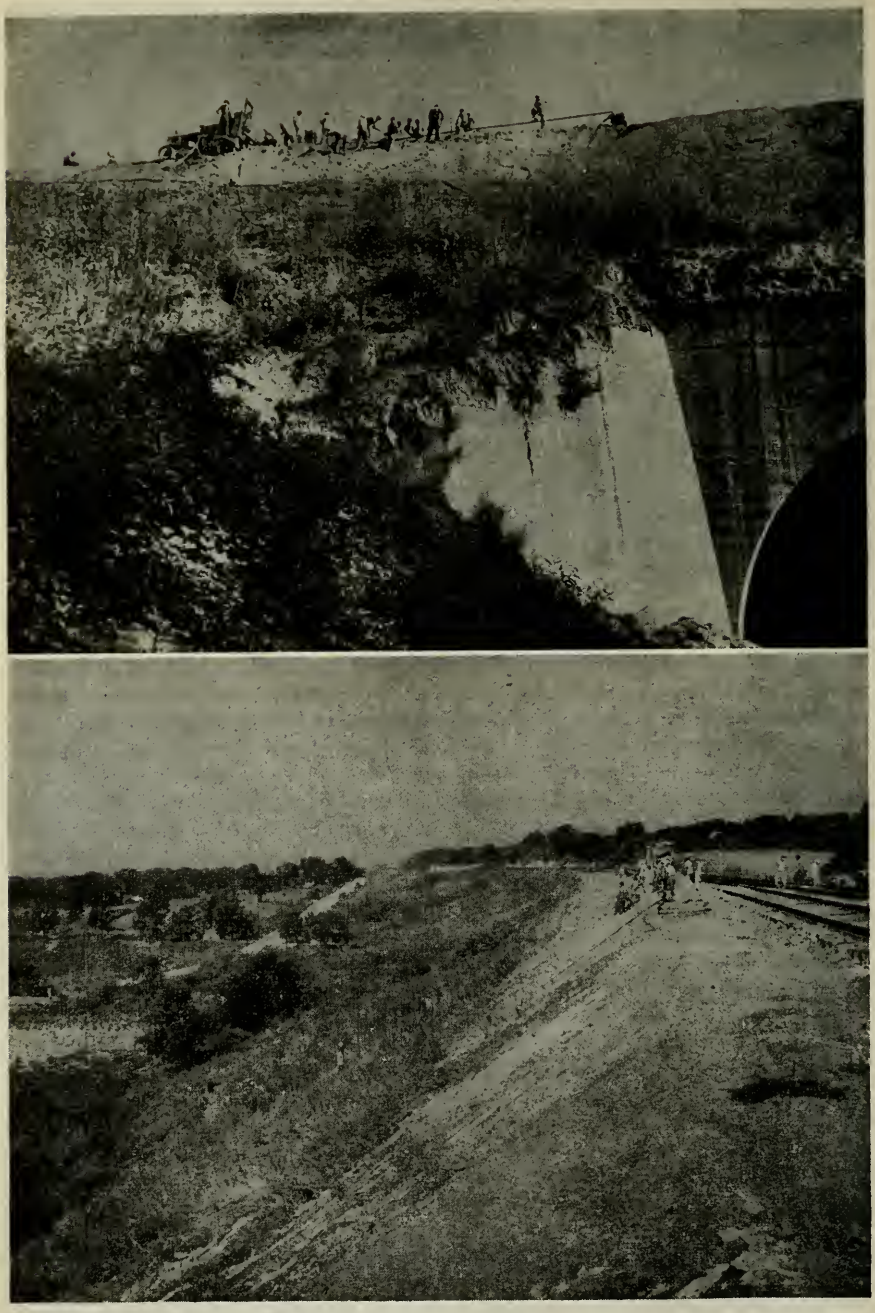


Fig. 5.—Burlington Fill near Ottumwa, Iowa.

fly-ash, 1 gal. asphalt emulsion and approximately 32 gal. of water. Grout was injected by means of two mud-jacks.

This work was completed in October 1947, and the results of the stabilization cannot be as yet assessed. During the grouting attempts were made to reach the zone of sliding with the injections. Movements in the fill have ceased and it appears probable that the stabilization will prove effective. A record will be kept of the savings.

Another interesting fill is now being grouted on the Burlington main line at M. P. 277, 1½ miles east of Ottumwa, Iowa. This fill has been a section of high maintenance for years and seasonally; slow orders are sometimes in effect. Fig. 5 shows several views of this fill and a profile of a portion is shown in Fig. 6.

As shown on the profile a number of drains have been installed previously, as well as a large number of piles dating from 1928, in an attempt to reduce maintenance costs on this fill. These measures were all successful in part, but the benefits have not proved permanent. As an example a section of approximately 4 rail lengths has slipped this

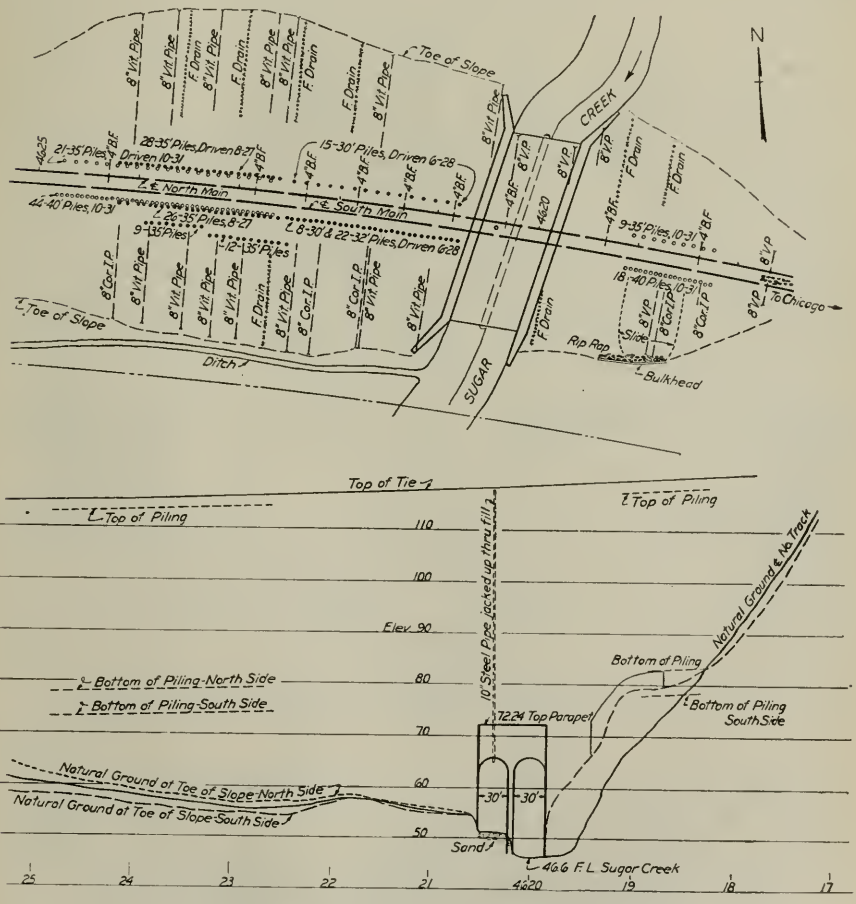


Fig. 6.—Burlington, Profile of Fill near Ottumwa, Iowa.

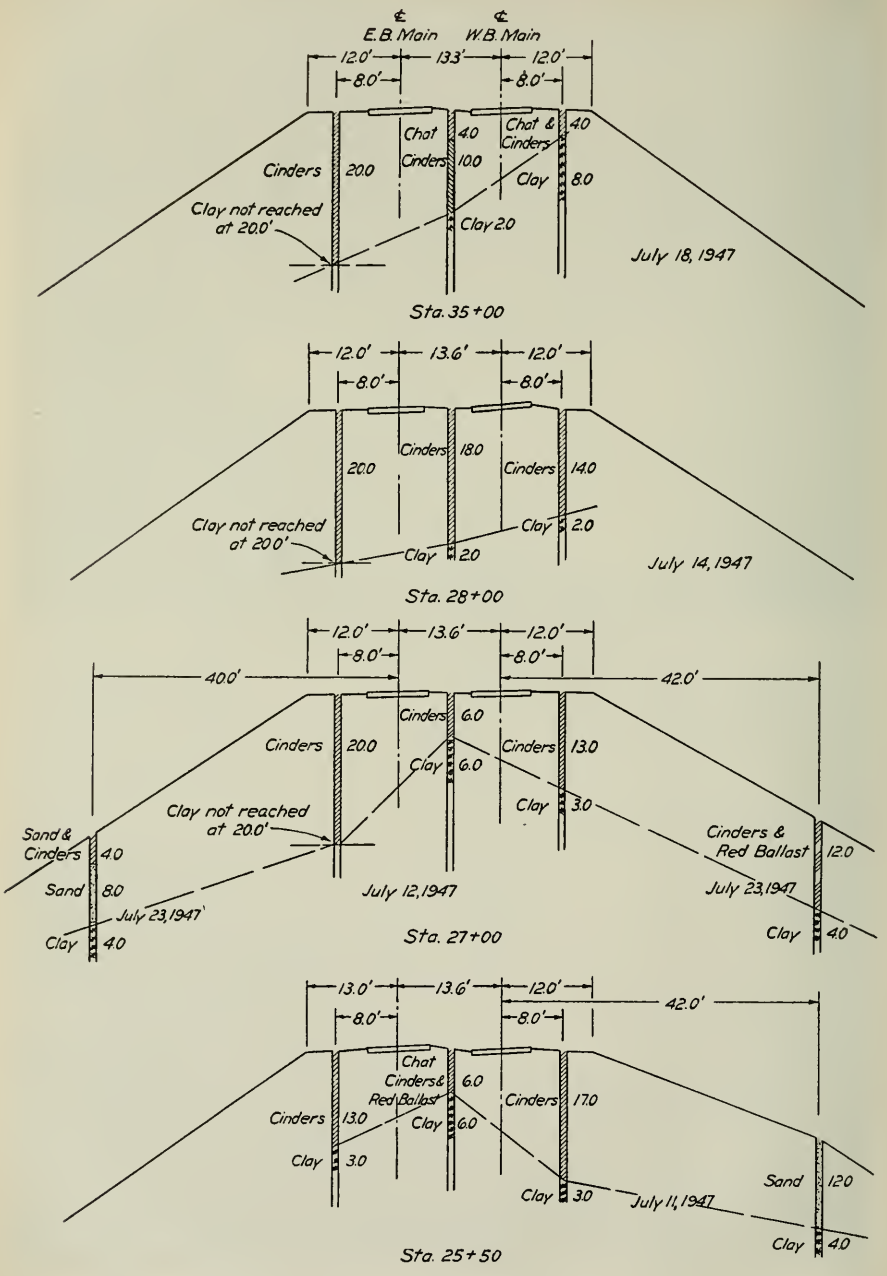


Fig. 7.—Burlington, Cross Sections Showing Borings, Ottumwa, Iowa.

year on the south shoulder of the fill and has required up to 3 ft. of cinders to restore the grade. See Fig. 5.

Fig. 7 shows a number of cross sections obtained by power drilling of the materials now in the fill. It can be noted that the clay soils have subsided from the original grade and that a considerable quantity of material has been needed to keep the top of the fill at grade. The borings were made with a gasoline electric auger drill as shown in Fig. 8. The conditions revealed by these borings are conducive to progressive sliding. It is probable that this sliding has rendered most drains ineffective and has moved the piling with it.

Two mud-jacks are used for the grouting. The mix is the same as that used near Beardstown. No figures on grout acceptance are available as yet, but for a considerable distance it will be high. Both slopes of the fill are being grouted; usually there are five rows of injection holes up and down, spaced 8 to 10 ft. longitudinally.

As this fill was being grouted at this writing no record of its performance is available, but movements on the shoulders have stopped. The attention given the stabilization work should insure good results.

Illinois Central

The Illinois Central completed this year a major grouting project on a fill 1521 ft. long and 30 to 40 ft. high immediately north of the bridge at M. P. 38.2 on the Edgewood cut-off, near Bluford, Ill.

This fill was constructed in 1925–1926. The soils are highly plastic, rather shaly clays from the roadway cuts in the vicinity. The fill had shown minor evidences of slipping in prior years but gave no indication of a pending slide. In December 1946 approximately 200 ft. on the east side slid out and down, cutting into the fill in a half moon section. The first movement was slow, but the final subsidence of about 15 ft. occurred rapidly. In the final position the top of the fill ended in a more or less horizontal position about 25 ft. below grade. Cinders were used to restore the grade. Operation of trains was under slow orders. Grouting was started in June 1947 and was completed in October.

Water ran from the fill after the slide and also during much of the grouting work. The fill is on practically flat land and there is no indication of subsurface disturbance of any depth. Fig. 9 is a profile of part of this fill.

As there were evidences of instability on other portions of the fill the entire length was grouted. Injections were made on both slopes and on the top, through points 8 to 20 ft. long according to the conditions encountered. From one injection near the toe of the fill the grout broke out on the center line of the grade approximately 40 ft. above. For the 200 ft. encompassing the major slide, grout acceptance was about 12,000 cu. ft. or 60 cu. ft. per track foot. Every effort was made to inject all possible grout. The grout proportions were 1 cu. ft. cement, 7 cu. ft. sand, 1 cu. ft. fly-ash, and approx. 35 gal. of water.

At present the slow orders have been removed and performance to date has indicated complete stabilization.

New York Central

The New York Central line between Cincinnati and Indianapolis rises out of the Ohio River Valley between Lawrenceburg and Batesvile, Ind. Through this section the grade cuts deeply into the bluffs and through thinly bedded limestone, shales and residual clays. These materials of highly plastic characteristics were used in the construction of the fills, which have continued to slip slowly and have caused high maintenance in this vicinity. Slow orders have been required from time to time.

Fig. 8.—Burlington, Power Auger Used for Soundings.

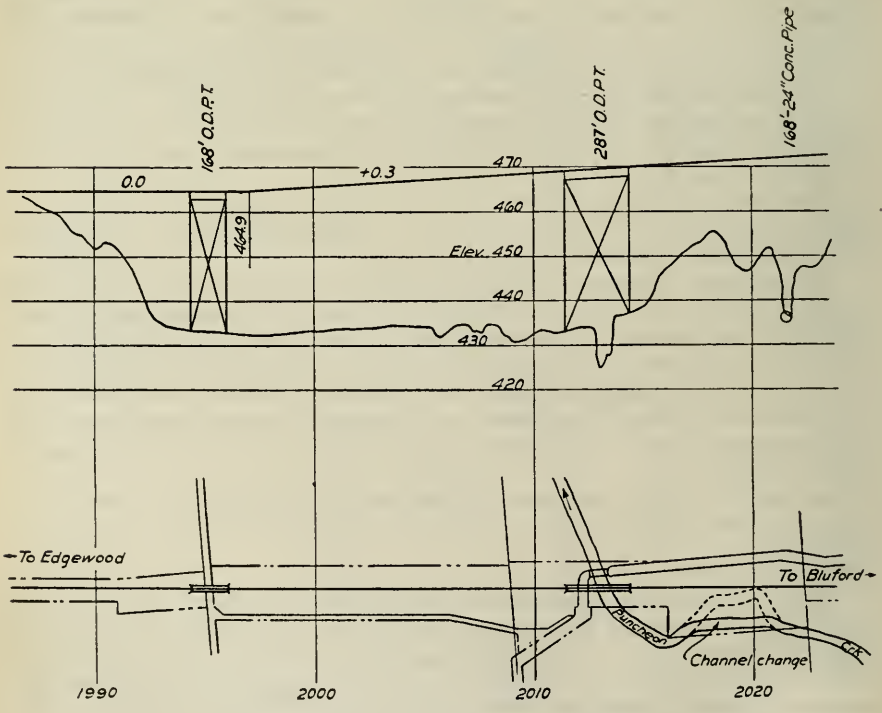


Fig. 9.—Illinois Central Fill near Bluford, Ill.

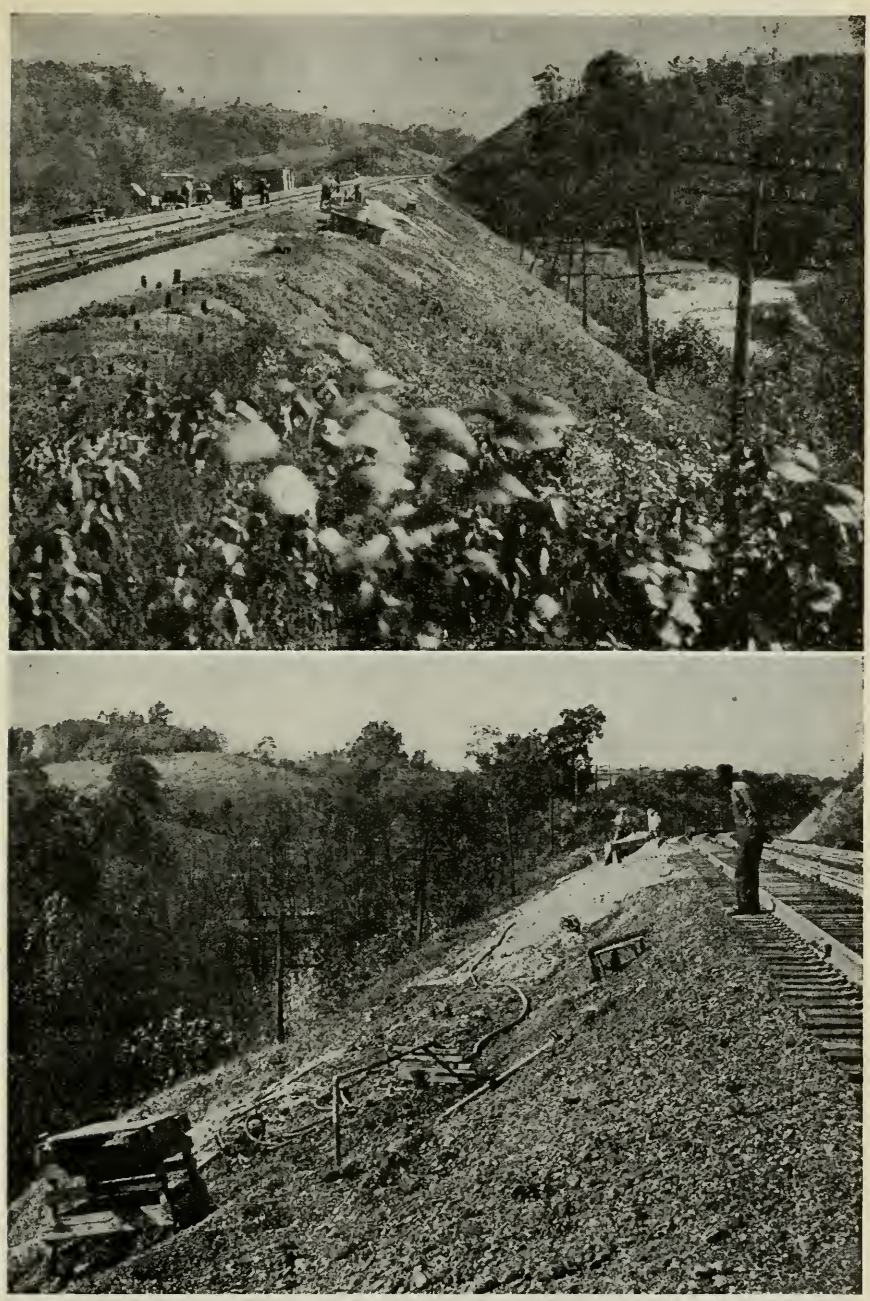


Fig. 10.—New York Central Fill near Lawrenceburg, Ind.

Fill grouting was started in 1945 and work has been done every season since. This year grouting has just been completed on the fill at M. P. 33 + 16. This is a 60 ft. fill, double tracked, now maintained on cinders which were used to restore the grade. Figs. 10 and 11 show several views of the fill. Rod soundings indicated that the cinders now have a depth of 20 ft.

This grouting project embraced only the 400 ft. of the fill on which slips have occurred. Since the slips were all to the south the grouting was confined to the portion of the fill south of the center line. Pneumatic equipment was used with the standard New York Central 1 to 1 mix. The procedure was similar to the grouting jobs described last year, except that most injections were made at a 20 ft. depth, or at a depth sufficient to penetrate through the cinders. Holes were also placed about half way down the slopes. All injection pipes were driven vertically.

The 400 ft. of fill accepted 6600 cu. ft. of gout, an average of 16.5 cu. ft. per track foot. Individual holes accepted over 200 cu. ft. The performance of other fills previously grouted, in the vicinity, is a favorable indication for the success of this year's work.

The approach fill to Br. 222 at M. P. 32.30 is similar. This fill was grouted in 1945. The 285 track feet grouted accepted 6400 cu. ft. of grout an average of 22.5 cu. ft. per track foot. Maintenance officers report that in the two years since grouting only very limited work of a routine nature has been required. Maintenance data are shown in Table 1.

Northern Pacific

Between Centralia and Chehalis, Wash., the Northern Pacific double track line crosses the flood plain of the Chehalis river on an 8 to 12 ft. fill. The present westbound track was the original line and the fill was widened and doubled tracked in 1911. Grouting was started this fall at M. P. 56 in a section where a pile trestle was in place on the original line until 1891.

This fill is subjected to very heavy traffic. The Union Pacific and the Great Northern also operate over this section, and as many as 85 movements a day are not unusual. Maintenance has been costly and slow orders have been required from time to time. During the winter, water often stands along the fill. Correction of the subgrade has been proposed for a number of years. One plan even called for the removal of the fill and rebuilding with gravel. In 1946 part of the fill was counterweighted by the addition of gravel in a berm along the toe of the fill. See Fig. 12. This addition was beneficial but did not eliminate track movements to the extent desired.

The fill is composed largely of plastic clay soils some of which were cast into the grade from adjacent ditch cuts. The ballast is pit-run gravel now pocketed to a depth of 4 to 5 ft. in places. There appear to be three types of instability in the fill, one from water-filled ballast pockets, one from a stress failure in the subgrade manifested by squeezes and plastic flow, and the third from a slipping of the newer embankment along the slopes of the old fill. A section of the fill was selected in 1947 for grouting to ascertain the applicability of that method to problems of this type. It is the first grouting work of which there is any record in the Pacific Northwest area.

The plan for grouting was designed to insure the injection of grout into possible zones of failure. Injections are made in both slopes and off the tie ends of both tracks. Ten-foot points are generally used on the shoulders and slopes, and 6 ft. points between tracks. In addition, sectional pipes up to 20 ft. in length will be driven in areas where there are indications of deep-seated movement. Longitudinally, injections will be made every six tie spaces with holes staggered in the various rows. During grouting operations the procedure will be varied as conditions dictate. The mix is 1 cu. ft. cement to 5 cu. ft. sand plus approximately 30 gal. of water.

Fig. 11.—New York Central Fill near Lawrenceburg, Ind.

Fig. 12.—Northern Pacific Fill near Chehalis, Wash.

This project was observed on only the first two days of operations. Since work is still progressing no final quantities of grout are available for this report. Grout acceptance ran high at the start of the work—higher than predicted for a 10 ft. fill. This high acceptance appears to be favorable to good results because the breakouts of grout have occurred in the fill itself. As an example, two holes 50 ft. apart on the west shoulder accepted 98 and 196 cu. ft. of grout before breaking out, and in both cases the breakout occurred on the center line of the fill.

Discussion

The injection of grout into fills is usually accomplished through holes on the slopes as well as from the top of the grade and these slope injections often account for a large portion of the acceptance. This gives weight to the conjecture that it is the voids in the fill rather than in the ballast that are responsible for the quantity of grout accepted. Grouting is not always accompanied by the ejection of water from the fill but this condition has been observed; also water has oozed from fills for several weeks after grouting has been completed.

It is not probable that much of the water seeping from fills during and after grouting is excess water from the grouting slurry. In most cases where water appears during grouting it is followed by grout and the flow stops as soon as pumping in that particular location is stopped. For the fill pictured in Fig. 4, seepage occurred prior to grouting and was accelerated during grouting but with no indication that the water was derived from the slurry. After grouting the flow slackened appreciably.

Several explanations of the presence of considerable voids in fills suggest themselves. Possibly the chief contributing factor may be the method of original construction. Construction trestles were commonly used and the fills made by side dumping off these trestles. Little or no attempt was made to obtain compaction and in many cases parts of the trestles were left in place. This is also conducive to poor consolidation. See Fig. 13. In one case, it appeared that winter construction was involved with considerable of the fill soil going into place in frozen chunks. In such cases the voids are comparable to those in a loose rock fill, until the chunks have thawed and the fill has consolidated. Prior to this the voids are available for the passage of whatever water may be present. Unequal consolidation and the arching action of the top and more compacted part of the fill may contribute to the void space.

In railroad fill construction past practice often has been to build at the lowest first cost. This has resulted in many fills with slopes as steep as it was possible to build by the means employed. Many of these fills probably have a safety factor as regards slope stability approaching 1, and any decrease in the shearing strength of the soils will result in a slide. If these fills have voids and water is available it is easy to conceive that this shearing strength can be lowered. A loss of slope stability and consequent movement will introduce other voids into the fill and sliding may be progressive.

This progressive loss of stability of railroad fills is at variance with experience with other earth structures, where strength often increases with age and service. It seems quite probable that the difference is due at least partly to the fact that railroad fills are subject to increasing moisture content and the resulting decrease in shear strength. These changes are caused by water passing into or through the fills.

The above discussion applies only to clay fills which are unstable in themselves. Most of the fills observed during the last year fall into that category. Fills may also be unstable even if they are well compacted and not subject to moisture variations, on account of movements below the fills in the original ground. An illustration of slides of this type would be a fill along a river bank where the river has cut into the bank, creating changes in the soil structure below the embankment proper, resulting in a

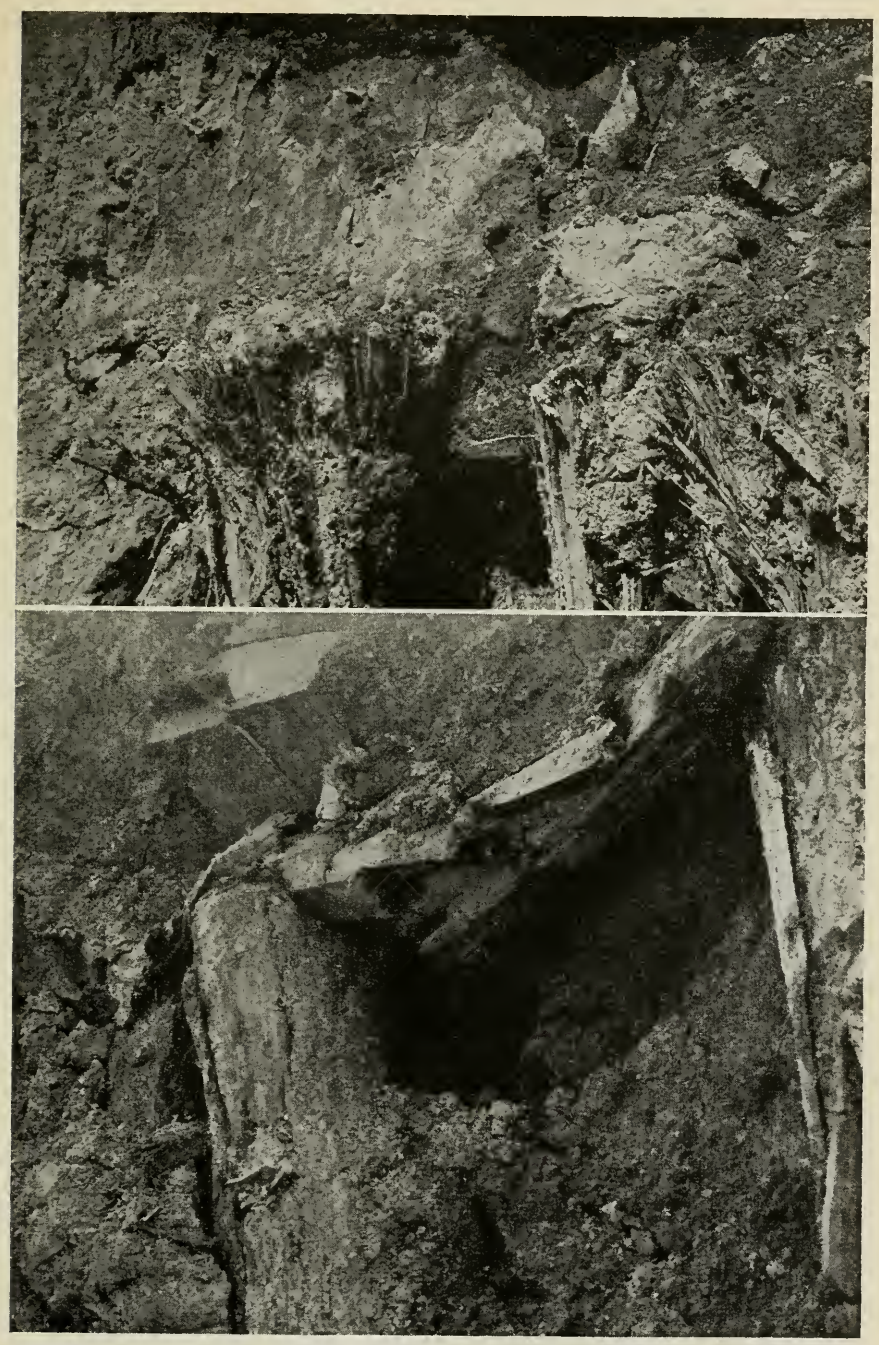


Fig. 13.—Voids in Fill Around Construction Trestle.

slide. Reports have been received that this type of fill has been grouted successfully but no observations have as yet been made.

One side hill fills or cut-fill sections underground water seeping into the fill may be an important factor in the instability. This condition is also possible on a fill between two cuts, but no examples have as yet been observed. On the other hand, surface water commonly enters fills through the ballast, especially where ballast pockets exist. This water is probably very detrimental to the performance of the fill. As was noted above, many fills, after slides have occurred, discharge water near the base of the sliding section. This flow has been maintained in some cases for several weeks. In one instance a trench was cut across the top 15 ft. of a fill, about 50 ft. removed from a recent slide that was still discharging water. The trench intercepted a considerable flow of water. The excavation disclosed ballast pockets about 4 ft. below the top of the grade through which water was flowing. It also showed large void areas around the old construction trestle still in the fill with little deterioration of the timbers and piling. See Fig. 13. This trench was cut into soil materials very similar to those in the slide but the fill here was only approximately half the height of that at the slide. The grade of the tracks was downward to the slide section for over 1000 ft. It is reasonable to infer that the tracks acted as a collecting channel, shunting the rainfall into the fill where the voids were largest and the stresses greatest, until the soil structure was weakened to the point of failure.

Whatever the original cause of a slide, once movement has taken place the disturbed soil will be subject to additional changes in moisture with attendant readjustment. As the cause of various slides is so complex and full investigation of fill conditions so difficult, a forecast of the action of any one fill that has a low factor of safety is not at present feasible.

It has been considered that the addition of grout under pressure might aggravate or accelerate the sliding of a fill prior to the setting of the grout. However this condition has not been observed. Because of the possibility of damage, a number of roads prefer to start the grouting near the bottom of the fill and work up, under the assumption that the greater resistance to upward flow will limit the penetration to the voids adjacent to the injection. Other roads have done fill grouting from the top of the grade using long points, with comparable results, and with no acceleration of the sliding condition.

Grouting of unstable fills is an outgrowth of the success attained in soft track stabilization by this method. During the last year there has been increased emphasis on this type of grouting, especially in the mid-west where the heavy rains of the spring and early summer were probably instrumental in accelerating fill failure.

The data in Table 1 show the maintenance cost before and after grouting on the jobs on which these data are available. The job giving the poorest results showed no savings in the labor required to maintain line and grade on certain sections of a large grouting project. Other sections of the same project showed savings up to 50 percent of the maintenance costs before grouting. According to supervisory officers the project as a whole has returned dividends in savings. Other projects all show a major saving and in a number of cases the saving effected is great. The permanence of stabilization by pressure grouting is yet to be proved, but indications are that most projects in service will return full value in labor savings alone within three to four years.

Stabilization by Drainage

An interesting example of slope stabilization by drainage is illustrated by Fig. 14. This site is on the Northern Pacific near Tacoma, Wash. and close to the Tacoma

Narrows bridge. The tracks here parallel Puget Sound on one side and bluffs of glacial gravel over 200 ft. high on the other. In many places this gravel is underlain by a heavy blue clay, an impermeable material which will stop the downward percolation of water. This condition may result in sloughs and slides in the sand and gravel, and at the point illustrated the slides of the bluff from above were of sufficient extent to affect traffic.

A drainage tunnel was constructed in 1930. It was originally intended to extend it through the bluff and into the draw, but during construction the heading broke out of the clay into the gravel. The material above the heading caved in and affected the ground surface to the extent that it was necessary to fill in the sink hole on top of the bluff. All but a few feet of the tunnel were lined at the time and the lined portion was put in operation with perforated pipes extending from the tunnel upward into the gravel. The driving of the remainder of the tunnel was abandoned. Water has flowed from the tunnel continuously since construction. Flow is now estimated at 250 gal. per min.

This installation has completely corrected sliding conditions at this location.

Stabilization by Sand-Filled Spud Holes

The Southern Railway on its western lines, has devised a system of subgrade stabilization by means of sand-filled spud holes. The following information is from a report on this method by D. W. Brosnan, general manager of the railway at Knoxville, Tenn. As yet no field installation has been observed.

Basically the method consists of driving a 12 in. by 12 in. timber spud a maximum depth of 8 ft., pulling the spud and immediately filling the hole with sand. Fig. 15 shows the layout of the spud holes that is called the 20 percent treatment. The following, quoted directly from the report describes details of the work:

> 1. A 12 in. by 12 in. timber, 10 to 12 ft. long is used as a driving spud. The lower 2 ft. of this spud is tapered to 10½ in. by 10½ in. This permits the spud to be set between cross ties and wedge the ties back, without injury to them, by driving. This avoids the necesssity for stripping ballast or removing ties. Unless the taper is provided the spud will gouge the sides of ties.
>
> 2. The spud is driven to a depth which will permit its being pulled with fair ease. If overdriven it cannot be pulled with the pile line and resort must be had to jacking which is extremely slow and the expense prohibitive. If a spud cannot be pulled with the pile line, it is sawed off rather than jacked. Usually several hundred holes are driven with one spud. If boulder formation underlies the track more spuds are lost than usual due to wedging in crevices. Places have been successfully treated where rock was only 12 to 18 in. under the track and where the spud went to rock under the weight of the hammer. Very few holes have been driven deeper than 6 to 8 ft., and most of them 6 ft. unless rock was struck. The depth of spud which can be pulled with ease by the pile line can be quickly determined and that depth should control. It is easy to over drive the spud; then it is lost.
>
> 3. It is preferable with a work train to have the sand loaded in a ballast car and not dump it in the track as from coal car. This latter results in waste of sand and fouling ballast. Two rubber tired wheel barrows are used to handle sand to the hole directly from the car, lowering the outside gate on the car for removal of the sand. Where a work train is not used the sand car cannot be handled by the driver and it is best to unload the sand on the shoulder where

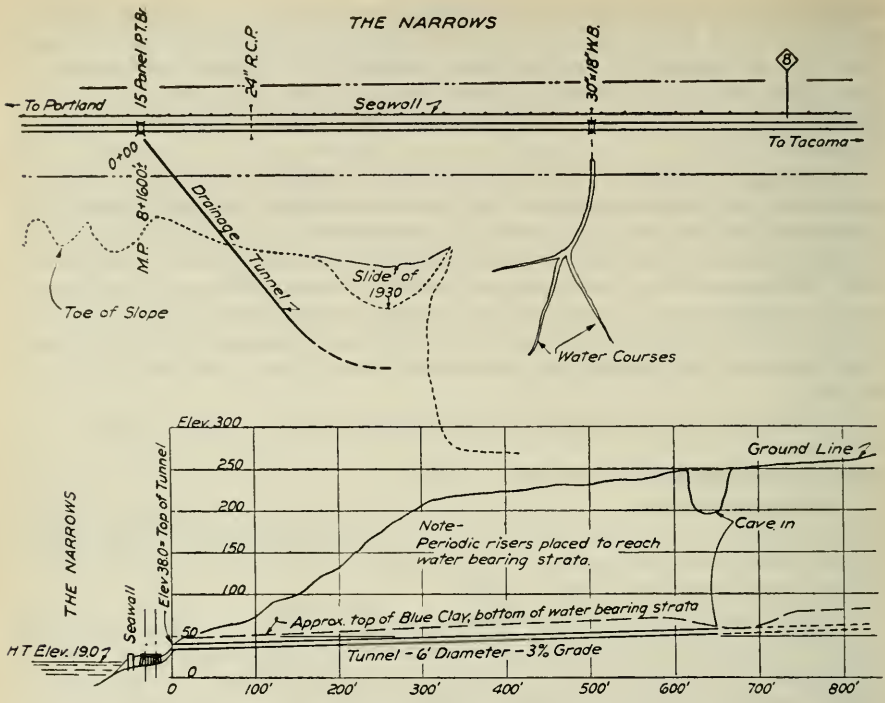
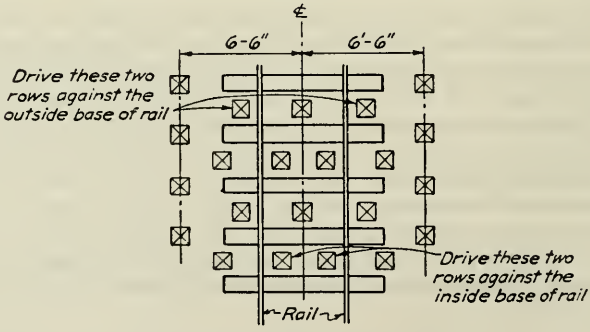


Fig. 14.—Northern Pacific, Profile of Drainage Tunnel.



20 PERCENT MIXTURE

☒ = Holes shown thus - 12" × 12" bridge timber used in driving holes.

Fig. 15.—Southern Railway, Typical Layout of Spud Holes.

the work is to be done. Any sand will suffice, as long as it is not quick sand and does not already contain a lot of clay. Ballast, cinders and such material are too coarse and do not mix readily nor do they provide sufficient surface area. It is not necessary to buy concrete sand, usually engine sand is used.

4. Driving spud and filling holes: Holes should be driven alternately working in stretches of about one-half to one rail length. If driving on both sides of center line, after the first series of holes are completed for one-half to one rail length on one side then the corresponding holes on other side should be driven. Then the process is repeated with the holes of the next series. Handling in this way provides:

> After spud is pulled, filling of hole starts at once and driver backs away, lands spud and hammer and both operations, i.e., filling holes and driving can go on without interruption. If driver moved only to next hole, spud cannot be landed until filling is complete because the hole just driven would be squeezed in and men filling hole cannot work properly if required to watch spud to avoid injury or burn. The average hole is driven and filled in 90 seconds, while occuping track; clearing time is, of course, lost.

As to the results of this stabilization, the Southern cites the cut near Camp Sibert, Ala.; where very soft track was encountered for 2000 ft. The cut was lowered 9 ft. in 1942 into plastic yellow clay underlain by irregular limestone strata at 4 to 8 ft. During rainy weather it was necessary to keep a crew in this cut continuously and in dry weather surfacing was required three times weekly. A 10 mph. slow order was in effect.

Since receiving the 20 percent treatment, which the Southern has found to be sufficient for very serious conditions, total maintenance for the first three months required 44 man hours. This is to be compared with the $5500 expended directly in wages during 1944. The slow order also has been removed, and the 44 hours cited above was applied under normal speed of traffic. The cost of the stabilization averaged about $2 per track foot.

The results of the first projects stabilized by this method have been very good and have indicated that this process has merit on the lower fills and soft track areas. The Southern Railroad is continuing this work at present near New Orleans. While it is too early to predict the lasting qualities of this type of stabilization, the first jobs reported have already returned the cost of the work. Costs of the work are still high and there are disadvantages in using on-track equipment. These factors can be made more favorable by use of off-track equipment which will be developed if the process continues to show good results. The investigation will continue.

Tie and Pole Driving

Investigations of stabilization by tie and pole driving were limited to installations on two roads. These installations have been in service for a period of years and have proved successful both from a stabilization and economy standpoint. The projects are on low fills and cuts, not exceeding 5 ft. In several of the fills discussed under grouting, piling up to 40 ft. in length had been driven. See Figs. 2 and 6. Stabilization by these longer piles did not prove permanently successful. However, reports have been received of long wood and rail piling installations that are fully successful. This discussion, however, will be limited to those installations of ties and short poles actually inspected in the field.

Missouri Pacific

In the past 16 years the Missouri Pacific has driven approximately 1,500,000 cull ties in wet cuts and low fills; also 400,000 poles, from 10 to 35 ft. in length, in unstable fills of greater depths. As part of this work in 1931, company forces drove 2246 black oak cull ties, 8 ft. long, over a 1900 ft. section of track between M. P. 475 and 476 east of Wichita, Kans. These ties were driven 1 ft. outside and to 6 in. below the two ends of each cross tie.

The track in this area is alternate cut and fill of less than 4 ft. The subgrade is principally clay topsoil. Underlying soils are also clays with occasional thin layers of limestone. A sample from the subgrade at M. P. 475 plus 15, 2.3 ft. below base of rail, in its field condition had a moisture content of 39.2 percent. The moisture content at the liquid limit of this sample was 53 percent, and at the plastic limit was 28 percent. The corresponding plasticity index was 25 percent, and the organic content was 4.5 percent. This is a highly plastic clay, and with the field moisture content well above the plastic limit subgrade instability is to be expected.

The ballast is fine chat approximately 27 in. deep and somewhat pocketed. Free water is present on top of the subgrade. Several holes were dug exposing the top 2 or 3 ft. of the driven ties. These were all in remarkably good condition after 16 years in place.

No squeezes or indications of subgrade instability are apparent on this section with the exception of two rail lengths on the north side of the track at M. P. 475 plus 18. Here there are several squeezes and the section foreman reports that occasional leveling work is required. On investigation of this area a thin limestone stratum about 2 in. thick was discovered at a depth of about 3 ft. No ties were driven here. It is interesting to note that in the one place where the vertical ties were not driven signs of instability are apparent.

The soil and moisture conditions described above are conducive to instability. The weakest portion of the soil structure is in the top 6 in. of the subgrade. The ties are driven through this into a relatively firm foundation, and have sufficient strength to resist movement. They can also act as drains for the escape of water.

Similar conditions are encountered just west of the tie installation on a 5 ft. fill where 10 and 12-ft untreated oak poles were driven under contract in 1945. These poles are spaced on 20 in. centers on both sides of the track. A total of 220 ten-ft. poles and 90 twelve-ft. poles were driven. These poles are 8 to 12 in. in diameter. The ballast here is 4.2 ft. thick and consist of 1.4 ft. of fine chats on top, a 1-ft. layer of stone dust, and 1.8 ft. of fine chats below. Tests on a sample of the subgrade 4.2 ft. below base of rail showed a field moisture content of 33 percent, a liquid limit of 45 percent, a plastic limit of 22 percent and a plasticity index of 23 percent. Water was present around the poles about 3 ft. below base of rail.

Originally this section of track also required excessive maintenance. A ballast application was required yearly to restore line and grade. The poles have eliminated all extra maintenance. It is to be noted that they were of sufficient length to permit a penetration of at least 5 ft. into the original ground.

The cost of the 1932 tie driving was approximately $0.98 per track foot. The 1945 pole-driving cost was approximately $2.95 per track foot. The savings on the first section in required line and grade restoration are estimated by the railroad at 3 man-hours daily. No figures on maintenance savings are available for the section on which poles were driven in 1945 but maintenance officers agree that it is proportionately greater, for the time it has been in service.

Santa Fe

The Gulf Division of the Santa Fe in the years from 1937 through 1945 stabilized 86,490 track feet by pole driving. These poles were unpeeled local timber of 8 to 12-in. diameter, driven at the ends of the cross ties to about 6 in. below the bottom of the tie. This work was done mostly by contract with a special driver devised for this work, but some was done by the road's own forces using a small on-track crane and pile leads. The average cost was $0.774 per track foot.

In 1943 and 1945 6851 track feet, included in the total above, were driven between M. P. 34 and 36. This section is on the flat lower coastal plain north of Galveston, a 2 to 4-ft. fill composed of heavy, very plastic clay soils. Three samples of the subgrade

Fig. 16.—Santa Fe, Typical of Track Stabilized by Grouting or Pole Driving near Galveston, Tex.

showed average moisture contents of 36 percent in the field condition, which is appreciably above the plastic limit of 26 percent. The average liquid limit was 70 percent and the average plasticity index 44 percent. The subballast consists of shells, and usually free water is present in the lower portions. Fig. 16 shows typical track in this area.

According to local maintenance officers the pole driving has been successful in materially reducing track labor. Present-day costs would be appreciably higher for the installations. A 1945 grouting project between M. P. 42 and 44, 5661 track feet, showed comparable original costs and comparable results, for very similar conditions.

Additional data on various projects of pole and tie driving will be obtained during the succeeding year, and an inspection will be made of present day practices.

Report on Assignment 6 (b)

Construction and Protection of Roadbed Across Reservoir Areas; Specifications

B. H. Crosland (chairman, subcommittee), W. T. Adams, T. A. Blair, A. J. Boase, L. H. Bond, J. P. Datesman, T. F. de Capiteau, J. C. DeJarnette, Jr., G. W. Payne, H. F. Pickering, J. W. Poulter, C. S. Robinson, A. W. Schroeder, F. H. Simpson, A. A. Winter.

This is a new assignment. Your subcommittee submits the following report of progress as information. Excellent reports from the chief engineers of 13 railways who have had experience on this type of construction have been received, but your committee has not yet studied this information in sufficient detail to render a very comprehensive report. In view of the considerable demand for information from several railroads who are faced with the problem, the following material has been prepared. It is hoped that it may be of some assistance, pending more mature study by the members of your subcommittee.

General

In approaching this problem, it is the general policy of the interested public agencies to reimburse the railways for all expenses they may incur, except for such items as may be considered betterment or profit. In arriving at the cost of the changes of the railway property, they have on certain projects in the past, paid to the railways a lump sum to cover the amortization of the annual increase in operating costs to the railroad where the relocated line is sufficiently longer than the original line to increase the wages of train crews; and to cover maintenance costs of increased mileage.

In some cases, the public agencies have been prevailed upon to set up a fund for amortization of extraordinary maintenance. On War Department projects, the U. S. Engineers have frequently been reluctant to approve such an expenditure on the ground that it is entirely intangible and cannot be accurately estimated. In lieu of this, however, they have generally agreed to disregard depreciation or condition percent of the line to be abandoned and have agreed to furnish or to pay for new materials used in the construction of the new line; it being their contention that the difference in value as between the depreciated materials abandoned and the new materials used, should offset any extraordinary maintenance. It should be noted here that several railroads have reported very heavy extra maintenance costs on new lines constructed through reservoir areas, which have increased their annual maintenance expense substantially over previous costs and far in excess of any advantages obtained in the increase of the relative condition percent of materials.

The question of salvage of the old line is one that is usually worked out by negotiations with the understanding that when the public agency pays the entire cost of the new line, technically the title to all salvage material in the old line is vested in that agency. In most cases the railroads have retained this salvage material and credited the public agency with an agreed valuation.

Procedure and Reimbursement

Generally in the past there have been three methods of procedure which are as follows:

(1) The public agency prepares all plans and specifications, and handles the construction in its entirety. While plans and specifications are being made and during construction, the project is subject to the inspection and approval of the railroad.

Up to the present time, this is the plan that has been most generally followed by the railroads. It has the advantage of freeing the railroad from all financial uncertainty but has the disadvantage that at times the construction work has not been carried out to the complete satisfaction of the railroads.

(2) Plans and specifications are prepared by the railroad but construction of the project is handled by the public agency.

This is really an alternate of (1) above and has been used by railroads with the thought that to some extent it would help to minimize the disadvantages of plan (1). Where this method is used, the railroads are reimbursed by the public agency for the expenses incurred in preparing plans and specifications.

(3) Plans and specifications are prepared and construction is entirely carried out under the direct supervision of the railway at the cost of the public agency.

Two general methods have been used for reimbursing the railroads to cover work done in this manner. The first of these is on a force account basis; that is, after agreeing to the general estimated cost of the project the railroad would proceed with the construction in the same manner as with one of its own projects, letting parts of the work by contract and doing parts of the work with company forces, and be reimbursed by the public agency on the basis of monthly bills; the final payment being based on the general audit of the cost of the general project.

Under the other plan, which has not been used very much to date but which seems to be gaining in favor, the public agency makes reimbursement on a so called "damage basis." In general, this means that such agency agrees to pay to the railway a lump sum of money as damages for the property to be abandoned equal to the estimated cost to the railroad of the construction of the new line. This lump sum is not paid in advance but is paid to the railroad in monthly installments approximately equal to the percent of the work completed, and when the work is entirely completed, final payment is made equal to the residue due and payable on the original agreed sum.

In carrying out the work on the basis of the first of these two plans of reimbursement, some railroads have experienced no great difficulty, whereas others have encountered difficulties, principally as a result of auditing delays and disagreements that have come up during construction.

While there are several cases where present negotiations are based on the second plan of reimbursement described above, your committee has knowledge of only one case where a project was carried out under this plan, and while this case was a federal project, it was not under the direction of the War Department. The report indicates that it worked very satisfactorily.

In general, it would appear advantageous for the railroad to prepare the plans and supervise the work, because the railroad accomplishes results that are more satisfactory to it.

The disadvantages at the present time, in view of rapidly advancing prices and uncertain conditions now obtaining, seem to be founded principally on the difficulty of estimating with any degree of accuracy total figures that the public agencies will accept. In some districts the agency insists that the agreement between it and the railroad shall name a ceiling figure beyond which no reimbursement shall be made. In such instances the railroad has insisted upon a stepped-up figure in the agreement 25 to 50 percent higher than the approved estimate.

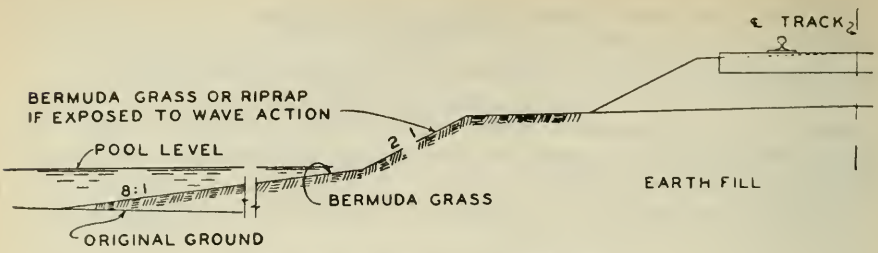


Fig. 1.—Use of Unusually Flat Slopes.

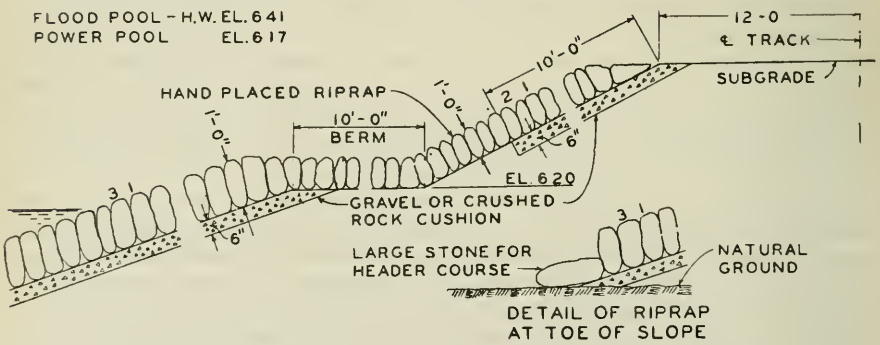


Fig. 2.—Construction with Normal Slopes, Hand Placed Riprap.

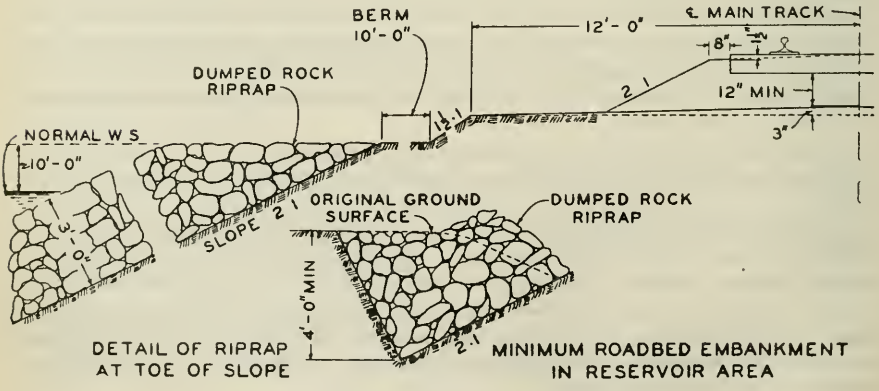


Fig. 3.—Dumped Riprap on Moderate Slope.

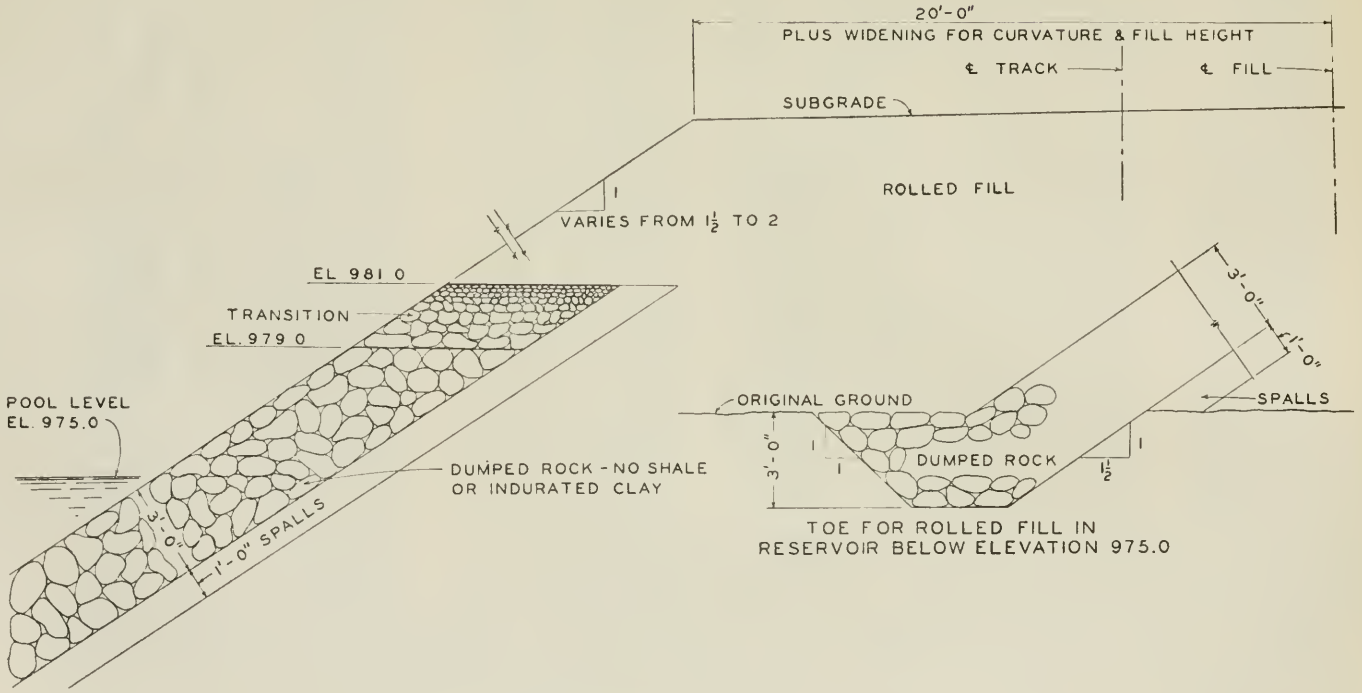


Fig. 4.—Manner of Applying Riprap on a Steeper Slope.

Appropriation of Right-of-Way

As to the right-of-way, the public agency will usually deed to the railway a right-of-way of substantially the same width as that along the existing line, and the railway in turn will deed to the agency its title to the lands to be abandoned. Where exigencies of construction require a wider right-of-way than that originally held by the railroad, the public agency has generally agreed on these additional widths.

Details of Construction

The plans and specifications for construction really fall into two categories, one being that part outside of the reservoir pool and the other embracing such parts of the relocation as involve embankments lying within the reservoir or inundated area. The work done outside of the reservoir will generally conform to the railroad's existing standards, and needs no discussion here. The work inside of the reservoir requires unusual roadbed sections; special methods of embankment construction and adequate slope protection. These features will be covered in recommended specifications to be presented at a later date.

The comments received embody a wide diversity of views, as to the roadbed section, based largely on soil stabilities. On the reported projects slopes of embankments through the inundated areas, have varied from 1½ to 1, to 8 to 1, and in a few cases as flat as 20 to 1. The usual practice, however, has been to maintain slopes of either 2 to 1 or 3 to 1, from the toe up to a point about 10 ft. above predicted high water, then a berm of 10 ft. and 1½ to 1 slope from there on up.

The crown for single track varies from 20 to 24 ft. but in more recent practice has generally been taken as 24 ft. For multiple tracks, this is increased by the distance between center lines of tracks.

In some of the earlier cases, hand-placed riprap was used in thicknesses of 3 ft., 2 ft. and 1 ft. depending upon the stream conditions at bridge ends; or, in the case of construction in the reservoir, according to the reach. In more recent negotiations, however, it appears that dumped riprap has been more generally specified. Dumped riprap has usually been specified in thicknesses from 18 to 36 in., properly toed in at the bottom of the slope.

In general, the riprap is carried up the slope to a point 10 ft. above predicted high water. This height, however, is governed to some extent by the reach and the resultant wave action expected.

Track Standards

The public agency usually will agree to furnish or pay for new rail, new fastenings, new ties and new ballast of the same standards as in the present track. In cases where the railroads have desired to build their relocation with rail of a heavier section than that of the old line, the public agency has paid the cost for rail of the weight in the old line, and the railway assumed the cost of the increased weight.

Figs. 1, 2, 3 and 4 depict typical roadbed sections used by some of the railroads on past construction.

Fig. 1 illustrates a case where unusually flat slopes were employed below pool level, on account of soil conditions.

Figs. 2 and 3 show slopes more commonly employed, Fig. 2 indicating a type of hand-placed riprap, and Fig. 3 a type of dumped riprap.

Fig. 4, with slopes somewhat steeper than usual, shows a different treatment for the dumped riprap.

PROCEEDINGS

PROCEEDINGS

Report of the Opening Session of the Meeting on Tuesday Morning, March 16, 1948; the Closing Session on Thursday, March 18; and other business not related to the Presentation of the Committee Reports

Opening Session, Tuesday Morning, March 16, 1948

The opening session of the forty-seventh annual meeting of the American Railway Engineering Association, held at the Palmer House, Chicago, March 16–18, 1948, convened at 9:50 a.m., President Armstrong Chinn* presiding.

President Chinn: Will the meeting kindly come to order?

I will ask the Board of Direction and the past presidents to please come to the platform.

This is the annual meeting of the American Railway Engineering Association. It is also, concurrently, the annual meeting of the Construction and Maintenance Section of the Association of American Railroads.

There is now seated at the table our Board of Direction and past presidents who are in attendance, and I take a good deal of pleasure introducing them to you.

(President Chinn then introduced the following past presidents who are no longer members of the Board: E. F. Wendt, G. J. Ray, W. P. Wiltsee and A. R. Wilson.)

The first order of business is the reading of the minutes of the last annual meeting. A printed copy of the minutes has been furnished to each member. If there are no objections, we will dispense with the reading. Since I hear no objection, the minutes will stand as written.

The next order of business is the president's report.

Address of President Chinn

This is the 47th Annual Meeting of our Association. Except for circumstances that compelled us to forego the meetings in two years during the war, 1943 and 1945, this would have been our 49th convention. That we are actually close to the half-century mark is indicated by the fact that 50 years ago this coming October, namely October 21, 1898, was the date of the first gathering of what was to become the American Railway Engineering and Maintenance of Way Association. The shorter form of name which we use today was not adopted until 1911.

The pioneers who laid the groundwork for our Association, built on a firm foundation. We have had to make few changes in the rules they laid down for the form and substance of our work, and none whatever in the basic objectives. What has been accomplished, therefore, through the years is owing largely to the wisdom of the men who planned our organization. The problems have changed with the times, the Association has grown with the volume and increased intensity of railway traffic and we have

* President, Terminal Railroad Association of St. Louis.

applied new techniques and more scientific procedures as they have become available, but the basic approach to the work—through committees—remains as it was planned for us 50 years ago.

The Purpose of the Association

To put it in the simplest words, the purpose of the Association is to provide the means whereby its members and others interested in railroad engineering and maintenance can study and work together in a united effort to develop materials and structures that will last longer with less maintenance expense; to devise tools, machines and methods that will make possible the more efficient and economical use of construction and maintenance labor; to develop plans and designs for tracks and structures that will permit a greater volume of traffic to be handled faster and more safely; and to disseminate, through meetings and proceedings, their findings so that all members and their railroads may have the benefits to be derived from them.

The various committees in their studies are carrying on research in a practical way, some of it in laboratories but most of it in the field under actual traffic conditions. This generally takes more time than in the laboratory but, where the answers can be so obtained, they are usually more conclusive. Man, progressive man, no matter what his occupation, is always carrying on research—he may not call it research but he is always studying and seeking a better and more satisfactory way of doing his work. That is why we have progress. Without progress any business or enterprise will stagnate and die. To me the heartening and stimulating fact about the world we live in is that there is no limit to the possibility for improvement. There is no final goal. We all know that in the years to come we will be doing a better job than we are doing today and the certainty that the means, the materials, and the knowledge to do this better job are here now, today, ready to be used if we can but discover them, is the incentive that spurs us on in our efforts to find them and enjoy the benefits they will bring.

Dues Increased

Although the AREA is now 49 years old, it was not until the first of this year that the annual dues paid by the members were changed from the figure adopted at the outset, namely, $10. It became my responsibility to inform you of the conclusion reached by your Board of Direction of the need for larger revenues, as set forth in my letter to the membership published in the AREA News for September 1947. And as noted in the report of the tellers appearing in the issue of the News for December 1947, the proposed increase in dues from $10 to $15 for Members and Associates and from $5 to $7.50 for Juniors was ratified by a vote well in excess of the two-thirds majority required.

This manifestation of confidence in the judgment of your Board of Direction is greatly appreciated and in return the Board offers the assurance that the increase in the revenues to accrue from the higher charges for dues will place your Association in a thoroughly sound financial condition, in spite of the uncertainties with respect to price levels in the immediate future.

The financial outcome for 1947 was more favorable than was anticipated in that there was an apparent excess of receipts over disbursements of $4.04. However, this showing was possible only because of a windfall of $1208.23 in the form of a refund of an employers' excise tax. Further than this it is only because the binder and the printer failed to meet delivery dates on orders for replenishing stocks, that charges for new Manual binders and a reprinting of the Track Plans were carried over into January 1948 instead of being applied to the 1947 expenditures.

Membership

The status of the membership is shown in a tabulation appearing in the report of the secretary. The total number of members, 2334, is the largest since 1932, while the net increase of 118 during the last 12 months is the largest gain since 1929. The progressive increase in membership from a low of 1880 in 1939 is most heartening—especially so, because it is not the result of any drive or campaign for new members. Experience has shown that members recruited as the result of competitive efforts as between railroads, committees, or otherwise, are not likely to possess a real interest in our work. However, we must keep in mind the need for an adequate and well distributed membership. There should be a reasonable balance in the number of members identified with the various railroads. Our Association will be of maximum benefit to the industry only if all railroads participate in the work and this condition can be realized only if all railroads are adequately represented in our membership roster.

One of the gratifying things I have noted about our membership during my term of office is the number of young men who are joining the Association. I take this occasion to welcome them and to say to them the Association needs them and they need the Association. As the years pass they will be assuming ever greater responsibilities with their companies and here, in the Association, they can, if they will, find much that will be helpful to them. In this connection I suggest to them that the way to get the greatest benefit from their membership is to apply for appointment to a committee and participate actively in its work. I know of no better way for a young man to broaden his knowledge, enlarge his friendships among railroad men, demonstrate to others in his profession his knowledge and ability and generally prepare himself to creditably discharge the greater responsibilities that come with promotion. That, after all, is the main reason why our Association came into being and now has well over 2000 members. Railroad engineers feel they derive a very real personal benefit which, in turn is helpful to the companies they represent, by associating together and pooling their knowledge and experience for the benefit of all.

Letter Ballots

During the last year the membership has demonstrated once more that letter-ballot consideration of a technical problem is not too cumbersome a procedure. Thus, in the November issue of the AREA News you were asked to vote on the proposal for an emergency revision of the drilling of 115, 132 and 133-lb. RE rail, and by November 17, a special committee of tellers had counted the ballots and reported a vote of 685 in favor of the proposal and 46 opposed.

Closely allied to this subject is the action taken by the Board of Direction a year ago in requiring the committees to take letter ballots of their own members on all matter to be offered for the Manual and stipulating that no proposition may be offered to the Association unless it receives a two-thirds affirmative vote of the voting members of the committee. This rule was adopted in the interest of orderly procedure and to insure that every voting member of the committee has notice of the contemplated recommendations. I believe it will provide a convincing answer to any possible charges of ill-considered or precipitous action on the part of the committees. Without doubt the imposition of this requirement has markedly increased the paper work imposed on the chairmen of the committees and we are all indebted to them for the efficient manner in which they have taken on the added burden.

Naturally, any innovation will be the source of complications and misunderstandings, but actually little difficulty was encountered. This will be entirely avoided in

another year by a thorough discussion of this problem as one of the topics to be considered at the next meeting of the committee chairmen. This annual gathering of the chairmen with the officers of your Association, initiated by President Akers in April 1946, has provided a much needed opportunity for an exchange of ideas between the chairmen and for a discussion and interpretation of suggestions for the improvement of committee practices and a refinement of committee reports.

It has been gratifying to note the increased activity of the committees during the year—a larger number of meetings and generally a greater attendance at the meetings. However, there is still room for improvement. With the more rapid turnover in committee membership as the older men retire from railway service, there has been an intensive effort to recruit younger members for service on committees. But this movement has not been entirely successful because the attendance record of these replacements on the committees has not been all that could be desired—indicating that in some cases, at least, there has been a lack of sympathetic support on the part of the superior officers. The solution of this difficulty is not a simple one and demands persistent attention.

Larger Appropriations for Research

Most gratifying is the evidence of a growing appreciation of the value of research in the field of tracks and structures in the form of progressively increasing appropriations by the Association of American Railroads. The total of the amounts allotted for 24 different projects together with the administration thereof for the current year is $291,840, which compares with an allotment of $234,428 for 1947, and only $69,250 in 1940. It is also a manifestation of confidence in the able administration of these funds by the Engineering Division research organization, headed by Mr. G. M. Magee, and in the sound judgment of our committees since these various projects, with rare exceptions, are initiated by them.

It is also a source of satisfaction to us that the research projects are bearing fruit in an increasing number of recommendations for revisions of and additions to the AREA Manual that are based directly on the data developed in the course of these various studies.

And here let me say that our Association is fortunate that the vice-president of the AAR, in charge of operations and maintenance, which includes the Engineering Division, is Mr. J. H. Aydelott, a practical railroad man of wide experience who thoroughly understands and appreciates the importance of the work being done by our Association and gives it his helpful support. You will have the pleasure of hearing from Mr. Aydelott a little later on.

Proposed Amendments of Constitution

In the April issue of the AREA News there will be submitted to you by letter ballot two propositions for the amendment of the Association's constitution. The first of these, which came to the Board of Direction from one of the committees, proposes a liberalizing of the requirements for admission so that consulting engineers would be eligible for admission to the grade of Member. The second proposal, which was initiated within the board itself, proposes a change in the consist of the Board of Direction. By that I mean that it proposes to reduce the number of past presidents on the Board from five to two and to increase the number of directors by three. The object of this proposal is two-fold. On the one hand, it is designed to reduce the number of years of service on the Board to be demanded of a member who accepts the nomination as vice-president. As matters now stand he must already have served three years as a

director, so with two years as vice-president, a year as president and five as past president, we are expecting him to stay on the Board for eleven years. On the other hand, by reducing the tenure of service of the individual, and keeping the number of places on the Board the same, we will provide opportunity for a greater number of the members to participate in the management of the Association.

I am sure you will agree this is a step in the right direction. I doubt if there is any other organization of even remotely similar makeup and objectives in which such a large proportion of the membership takes an active part in the creative work that is being carried on. The committee members have a right to feel that they have a real stake in the Association and its accomplishments. Without question the results are more authentic and truly representative because there are so many of them. On the other hand, it must be recognized that the general supervision of our varied activities must be conducted by a group of limited size. Nevertheless, I am heartily in favor of the opportunity now afforded us for even the small increase in the number of members who will be enabled to take part in the work of your Board of Direction.

In closing I want to take this opportunity to express my appreciation for the unselfish efforts of the committees and particularly their chairmen in carrying on the important work they are doing, and for the cooperation and wise counsel it has been my privilege to receive from the Board of Direction during my year as your president. I am also indebted to the members of the headquarters staff for their loyalty and industry on behalf of our Association. They have done a splendid job.

President Chinn: The next order of business is the reports of the secretary and treasurer. I will ask Mr. Lacher, the secretary, to present these reports. Mr. Lacher.

Secretary's Statement*

Secretary Lacher: In the address which you have just heard, you have received a very excellent summary of the affairs of the Association during the last year.

The reports of the secretary and the treasurer present this same picture in considerably greater detail, but no good would be done if I were to attempt at this time to give you another summary of what we did during the last year.

On the other hand, I sincerely wish that some of you will read these reports. Perhaps a few of you have. The treasurer's report is gotten up in such a way that you can get the picture at just a glance. In the secretary's report we have presented as much of the information as possible in tabular form, with the hope that, if you become sufficiently interested to run through these tables, they will intrigue you sufficiently to read the running text as well.

Without attempting, as I said before, to give you any further review of the work of the Association during the last year, I would like to give added emphasis to one point made by your president, and that is that this past year has been one of greater Association activity. There has been a marked increase in the number of applications for membership.

Right there I want to point out that we have to get in about 100 new members each year just to make up for the losses that we suffer due to deaths, resignations and

* For complete reports of secretary and treasurer, see, pp. 841–851.

other causes. But during this past year we took in enough new members and got back, by reinstatement, a sufficient number of former members so that the total of those two groups added up to more than double the number of people who dropped out, with the result that we had a net increase of 118 in the membership, bringing it above 2300.

The point I want to make is that, when you have a large increase in membership, you also have a pronounced increase in the demand for places on our committees. This year that imposed quite a task on the Board Committee on Personnel which attempted to solve the problem in two different ways. Not only did the committee do what is normally done—effect a turnover in the membership of the committees by releasing the less active men and putting new men on—but in addition to that, there was an appreciable increase in the over-all number of places on the committees. I think the total is larger than it ever has been before. That puts an added job on the chairman of the committee. Your president laid some stress on that point.

He mentioned one thing, for example, this business of having to take letter ballots of the membership of the committees on every proposition to add to or to revise the Manual. But that is not all. Our work is getting more involved all the time. As you know, some of the committees have assumed considerable added responsibility in the way of research work.

Then, too, we seem to have more collaborations with other organizations. That, too, is quite a job. I am rather amazed how some of the committee chairmen can keep track of these rather involved collaborating activities.

In addition to the size of the committees, we have had this elaborate change of personnel. Even where there is no change in the individuals on the committees, as anybody knows who has had to keep up a membership list—a lot is involved in knowing where the members of the committee are, after they have been shifted around on their properties.

We in the office are trying to do what we can to help the chairmen of the committees out in some of this routine, but, unfortunately, we just are not equipped to conduct a secretarial service for 21 different committees. I wish we could do it. It is something that the chairmen of the committees are entitled to, but we just cannot give them what they should have along that line.

I realize that all of you have some idea of what the chairmen are doing for us. It has been well said many times that it is the committees, and the chairmen of the committees, that are the backbone of this organization. But I thought you ought to have just a little bit better picture of this little known side of what it means to be the chairman of a committee.

The printed report of the secretary records the death of 37 members. Since the secretary's report was prepared, four other members have died. Included among the departed were two of our past-presidents, G. W. Kittredge and W. D. Faucette. There are also three charter members, one of whom was known to many of you, E. E. R. Tratman. There were also many others whose unselfish devotion to the work of the Association should be an inspiration to all of us. (Applause)

President Chinn: You have heard the reports of the secretary and treasurer. What is your pleasure? Do I hear a motion that they be accepted?

(Upon motion made and seconded, the reports of the secretary and treasurer were accepted.)

President Chinn: As I previously mentioned, the American Railway Engineering Association is also the Construction and Maintenance Section of the Engineering Divi-

sion, of the Association of American Railroads. It is our privilege to have with us today the head of that department who, in addition to problems of engineering, must deal daily with all the matters that come to the attention of a railway operating officer, namely, transportation, car service, power and equipment, freight claims and the like; in other words, he is in a position to bring us a message concerning the broader import of the problems facing the operating departments today.

It gives me great pleasure to present to you Mr. J. H. Aydelott, vice-president, Association of American Railroads. Mr. Aydelott. (Applause)

Address of James H. Aydelott

Vice President, Operations and Maintenance Department, AAR, Washington, D. C.

Your president conferred quite an honor upon me in asking me to take part in this program. I am not addicted to much public speaking, but a group of railway men, such as we have here today, is familiar to me through the years which I have spent in the operating, construction and maintenance departments.

I thought, in listening to your president's report, that probably few of us realize that we represent about the only free railroads left in the world. We are still operating under the private enterprise system, while the railroads of all other countries have passed into the hands of government and are operated as a government agency. It is something to think about.

We have a duty to our industry and to ourselves, to see to it that the railroads of America and our Canadian brothers stay as they are in the leadership of the world.

American standards, many of them originated by this Association, are spreading throughout the world on the railroads that we have touched in the last six or seven years through our war activities. The gage of railroads is being changed throughout those countries where they have had the old-fashioned method of transferring wherever the gage changed, and they are using our motive power and shop methods, your engineering methods, your rail standards and track structure generally. So, we are coming at least to the realization of what an organization such as this and the other engineering associations finally can do. But we must keep ourselves free, as we have been, in order that this excellent example may continue to spread and dominate the railroad industry all over the world.

It is the prerogative of the speaker to depart more or less from a prepared talk, particularly an operating man who is not gifted with the art of speaking, and I shall do so throughout my talk.

I have tried, in my position with the AAR, to devote some time with all of our different departments. In 1947 I took part in the meetings of almost all of our sections and divisions. It simply brought home to me more clearly what a vast undertaking we have in the railroad industry, keeping a sound physical plant, operating it efficiently and keeping our customers pleased.

The damaging and losing of freight in the year 1946 cost the railroads about $100 million. In 1947 it cost the railroads $120 million. Now, you men have a stake in that loss. I think, to the extent that we fail to control it, the money must come out of the expenditures on roadway and equipment. One hundred twenty million dollars in 1947 would have reballasted a lot of track. It would have relaid a lot of track. Some of our

loss and damage we know is due to our equipment. Our trucks don't ride as they should in freight service. I think little of it can be charged to the track, although there are some indications that there has been some damage to carload freight and to l.c.l., because of track irregularities, but those things are rare. We are conducting intensive research in 1948, to bring out certain characteristics in the construction of trucks of the freight cars that we know is causing the lading of cars to be seriously injured en route.

We find we do not have wheels properly mounted, properly centered, producing eccentric action. We have axles that are not true. We have wheels that do not properly tram in the truck. A lot of details of that kind we propose to engineer as best we can, through our Research Department, and see if we cannot get our freight car condition on a perfectionist basis, so we will be able to eliminate this tremendous waste that is going on now.

I shall discuss today principally our research activities. Research is just about what the word implies. You search for something to meet a particular condition, and, if you fail to find it the first time, you re-search. I have had quite a lot of experience in practical research, and I will devote more of my time to practical research rather than to the technical or laboratory end of it.

I remember when I was located in the far west, where I had a staff composed more than 50 percent of what we called boomers. You all know what a boomer is. We had been buying, and all the railroads had been buying, what we called mineral seed oil for lanterns and signal lights.

Somebody conceived the idea that was pretty expensive oil and we should try to find out if we could burn kerosene. Some of the manufacturers produced some burners that gave promise for the use of that cheaper grade of oil.

Out in Wyoming we have at times, and I would say perhaps for 30 days at a time, prevailing winds that will probably average about 40 mph. So, they sent six of these lanterns out to me to test, knowing we had both the wind and the operating conditions everybody else had.

I gave these six lanterns to six switchmen, four of whom were boomers. We had one crew on the second shift and one on the third shift to which we gave these lanterns. So, in due time I thought I ought to have a report on what they did. The third shift men came in to see me when they went off duty. I said, "How did the lanterns work?"

The spokesman said, "Boss, they do fairly well in giving a proceed signal and do fairly well in giving the stop signal."

I stopped him there and said, "I will make a favorable report on the lanterns."

He said, "They are not much good on the slow signal."

I said, "You don't use that signal unless you are in the yard."

Nevertheless, the lanterns were adopted. My house was about a mile away. We could hear the oil cans rattle along. I knew they didn't know what an easy signal meant.

I shall devote the time afforded me to a discussion of the value and necessity of research activities to explain why the Association of American Railroads, your Association and others allied with us are stepping up and expanding their research programs. It will be agreed that if our American railroads are to meet the future transportation requirements of the nation, every known means of improving the character of their roadways and equipment must be brought into play.

Each decade in the past history of our railroads has brought new problems, and each succeeding decade in the future can be expected to be no different in that respect. The present-day slogan of our railroads may properly be said to be "greater speed and better service without a sacrifice of safety or comfort." To fully reach this desired

objective will require cooperative effort within groups such as yours and in others in their respective fields in the railroad and supply industries. The progress made by the railroads in the two decades immediately preceding World War II, much of it as a result of intensive research both within and without the industry, enabled them to handle record-breaking tonnages primarily of materials required in the war effort, with about a half million fewer freight cars and many thousand fewer locomotives than were available in the 1930's. Without a constantly improved roadbed and improved equipment, no such performance as this would have been possible. The people of this country in analyzing those results have now generally accepted the view that not only the economy but also the security of this nation will depend to an ever-increasing extent upon the maintenance of sound and healthy railroads.

Must Advance Research Activities Now

There is scant opportunity when a national emergency arises for the railroads to then make any material progress toward the strengthening and expansion of their facilities. Not only are materials then in scarce supply, but labor with which to perform improvement work or even the necessary maintenance work is not generally available, and where available the frequency of train movements is such as to prevent a satisfactory output being secured. With these experiences so fresh in our minds, the railroad industry must take full advantage of the opportunity afforded in peacetime years to advance their research activities as the AAR and many of the individual railroads are doing, and to plow back a sizeable share of their earnings into improvements of the plant.

We hear a great deal these days about scientific research—particularly railroad research. We have heard that the railroads are not doing all they should do in this respect; that they are spending only a few paltry dollars in investigation and study; that they are not "modernizing" their plant and methods. We are told that, as a result, railroads are making very little, if any, progress, and that immediate steps should be taken to correct this situation.

Those of us who know what is going on in the field of railroad research and progress might be disposed to disregard such statements. But we cannot afford to do it. Unfortunately, this kind of talk is coming from some people whom the public has come to regard as authorities on railroads and railroading. Consequently, there is a segment of the public that is actually beginning to believe that our railroads are "asleep at the switch" when it comes to scientific study, and that the railroads are far behind other industries in technological developments and research. It is a false impression that we in the railroad industry do not want the public to have, and we should make every effort to correct it.

As we in the railroad business know, research started on the railroads with their very beginning, and has continued ever since. As a result of this continuous and unbroken chain of development, our railroads have progressed to a point where never before in their history have they been so efficient. Indeed, if it were not for the progress they have made and their attainments in efficiency, they would not now be able to handle a record-breaking peacetime traffic with the amount of equipment and the tools they have to work with.

Even those who have been critical of research activities on the part of the railroads have freely admitted that the railroads did an outstanding job during the war and are doing a tremendous job now in the face of great difficulties. Surely a transportation agency which has done what the railroads have done since 1939 must have made great strides in improving their plant, equipment and methods. And such improvements could

not have just happened or could not have been brought about merely by waving a magic wand. They came about through the investment of billions of dollars in better plant and facilities and by exhaustive research.

Must Never Be Satisfied

But no matter how fine a job the railroads do, they never have been and never will be entirely satisfied with their performance and accomplishments. They will always be looking for ways to improve their services and operations. They are fully aware of their responsibilities to the public and to the nation, and know that they cannot meet them by standing still. They know that real progress cannot be made without intensive and continuous research, and they will never be caught napping in this respect.

In fact, today—at the very time when there are those who say that railroads are backward in research—the railroads are actually doing more research than ever before and doing it in more directions. This is true not only of the railroads individually and collectively, but also of the manufacturers of the 100,000 different items that the railroads need and use in their daily operations.

Take the AAR, for example. Anyone who takes the time to go over the Association's annual report for 1947 and the outline of activities contemplated by the various departments of the AAR during the coming year cannot help but be impressed with the large number and variety of the research projects being carried on by this organization alone As a matter of fact, the AAR today is doing more in the way of research than it ever did at any other time.

The same can be said for the AREA. As you may know, the Engineering Division is carrying on more than 60 projects to improve track and structures, and this is only a part of the work it is doing. The total authorization for Engineering Division research for the present year is about the same as the aggregate amounts appropriated in the years 1937 through 1940.

There are those who measure the amount of research by the amount of money being spent on it. I have never felt that this was a true measurement of the extent of such activities. But even by the dollars-and-cents yardstick, the railroads are high among the leaders of industry in technological developments and research, as they spend millions of dollars each year for scientific advancement.

One of the reasons that the general public is unaware of the great amount of research being done by the railroad industry is that there is so little that is spectacular about it. It is not often that the work we are doing along scientific lines can produce such an eye-catching development as the streamlined train. Moreover, our research activities are not centralized and never can be.

I like to think of the railroads as a great research laboratory 227,000 miles long for devising and testing improvements in plant and equipment and in methods and services. Actually, that is exactly what they are, because over these thousands of miles of tracks the products of laboratories and inventors are tested under service conditions and in relation to existing practices.

I have said that there is more railroad research being conducted today than at any other time. The reason for this is that railroad research has become more important than ever before, and its importance is being recognized more than ever before. The best evidence of this will be seen in the increasing appropriations for such work and the increasing number of research projects and the number of people who carry them on.

To me, this is extremely encouraging, and should be encouraging to those who devote their time and energies to railroad betterment. But we should not overlook the responsibilities that go along with research work.

One of these responsibilities is that the money appropriated for scientific investigation be spent prudently. There will always be errors of judgment, false starts and blind alleys in research. These are to be expected. But the time must come eventually when it is necessary to decide whether the chances for tangible results are so remote as to indicate the wisdom of terminating a project. In such cases, it is far better to admit a temporary setback, perhaps even a failure, than to continue throwing money away.

Another responsibility is the application of results. Some people are under the impression that research work has no purpose other than to confirm their own preconceived ideas or established practices. To these people, any data running counter to their ideas or usages should be disregarded as faulty. If railroad research is to attain what it sets out to accomplish, such people must have the courage to admit when they are wrong. Otherwise, time and effort and money expended on such work are wasted and real progress is retarded.

Adoption or adaptation of the results of scientific studies calls for a considerable amount of give and take. After reliable data have been developed upon which to predicate recommended design, it is often necessary that current standards be given up in the interest of the common good. It is only by doing so that the individual railroads, working through an association such as yours, can derive the maximum benefit from research work, and also from the other studies carried on by your committees.

Those of us who have been identified with the railroads for many years have seen tremendous progress made. We have seen the so-called impossible happen time and again. We have seen the railroads attain peaks of efficiency that many thought could not be reached.

Marked Advances Have Been Made

I think we can look ahead to even greater progress and accomplishment. I think we will see technological advances that now are undreamed of. While the basic principles of railroads and railroading will be unchanged, the railroads of tomorrow will be as different from the railroads of today as today's railroads are different from those of 25 years ago.

There will be no *revolution* on our railroads, because we don't have revolutions on them. But there will be *evolution,* and this will continue and be intensified.

Railroad research will be carried on by every railroad employee, because every railroad worker, no matter what his job, is, in a sense, engaged in research. The practical track supervisor who studies the behavior of his track under traffic; the road foreman of engines who observes performance under service conditions; the man who keeps an eye on what is gotten out of materials and supplies—all of these are as much research people as those who work in laboratories.

Railroad research is necessary to help maintain what we like to call the "American way of life." It will help to insure the continuance of the free enterprise system in this country—a system by which America was developed and which has made America great. We have seen and are seeing today what happens to nations which rely on other systems of getting things done, and there is not one of us who would change our system for any of them.

The maintenance of our democratic system depends on many things, the most important of which is its ability to produce results. In this connection, our country needs and must have good railroads at all times, and that means railroads which forge ahead. This our railroads will do through scientific research—the sort of research that has made our railroads today the finest in the world.

President Chinn: Mr. Aydelott, on behalf of the Association, I want to thank you for coming from Washington to give us such a stimulating and informative address.

We have a long program before us, and, in order to conserve as much time as possible, it is desirable that we be prompt in our attendance and confine our remarks to the discussions.

The privileges of the floor are extended to members and to interested visitors. We hope you will feel perfectly free to discuss the committee reports as presented. This invitation is extended particularly to the younger members of the Association.

I wish at this time to direct your attention to the fact that we will close our session this afternoon at four o'clock to permit time for you to visit the exhibition at the Amphitheater. The National Railway Appliances Association is providing bus service.

Sometime ago our Association had two committees, known, respectively, as the Committee on Signals and Interlocking and the Committee on Electricity, and these two committees presented to us reviews of current developments in these two important fields and also an account of the activities of the Signal Section and the Electrical Section of the Association of American Railroads.

Since it has seemed better to obtain this information firsthand from representatives of the sections, the committees were disbanded. And, in accordance with the custom established last year, we will hear from the chairmen of the two sections.

Our first speaker is Mr. J. A. Beoddy, chairman of the Signal Section, and superintendent of telegraph and signals of the Norfolk & Western Railway. Mr. Beoddy.

Address of J. A. Beoddy

Chairman, Signal Section, AAR, Roanoke, Va.

It gives me a great deal of pleasure to appear before this meeting as chairman of the Signal Section, to represent it and discuss recent developments in railway signaling practice in relation to railroad operation and the part played by the Section and its members in these developments.

The policy of having the chairman of the Signal Section address this meeting was instituted two years ago, and I am the third one to be so honored. My predecessors in office outlined some of the more tangible results which have been accomplished as a result of developments in signaling during the war which were brought about by the necessity for handling the greater burdens of traffic which were placed on the railroads as a result of the war, and which played a large part in solving these problems and assisting the railroads to make their records during that period and subsequently.

Signaling is a portion of railroading which in itself is not spectacular, but since its inception, primarily to increase the safety of train movement, it has become more and more a necessity in railroading, without which modern high speed operation would be impossible. The modern trends in signal engineering have been to assist in increasing speeds and eliminating train stops, always with safety as the fundamental, and upon this today depends the effectiveness and economy of modern train operation, which is the goal toward which railroads are striving. I cannot report that during the past year there has been originated any novel or outstanding feature in railway signaling, but can report that there has been a steady improvement in the systems which were already in use, looking to refinements in design and adaptation and the continuing application of all of these systems where they will result in greater safety and facility of operation.

Centralized Traffic Control

As most of you are aware, the most outstanding development in the signaling field in recent years has been that of train operation by signal indication, usually referred to as centralized traffic control, with switches and signals over a large section of territory controlled from a central point. This is being applied more and more in meeting operating problems and is assisting in obtaining higher speeds and fewer delays with a maximum of safety, which contributes to economy in operation and which offsets to some degree the rising costs in railroad activity.

This is particularly true in the application of CTC to the problems of reverse operation on multiple tracks, where advantage of this form of control can be taken to use both tracks of a double track for the movement of trains in the same direction at times when there is no interfering movement. This means the taking of full advantage of all of the facilities available and in many cases will postpone the construction of additional tracks in the same manner in which its application to single track operation has postponed the construction of double track.

The application of modified systems of CTC, in which train movement is directed by the dispatcher from a central point but in which the switches are not controlled, is being given careful study and several installations of this type have been made. There is a broad field for these applications covering thousands of miles of light traffic lines which are now handled by manual block or by time table and train orders. Also, the use of spring switches on passing sidings in absolute permissive block territory on single track is being studied and several installations made.

The function of the signal engineer is to apply the devices available to the operating problems which arise, and it is the duty of the Signal Section to keep abreast of any developments in its field and to report on these developments at its annual meetings, where they can be discussed and afterward printed in its literature so that knowledge of them may be disseminated through the industry.

The committees of the section are constantly developing requisites for the various systems of signaling as the need for them arises and establishing specifications for various materials and apparatus which enter into signal installations, in order to provide, not hard and fast standards, but those which can be recommended for these materials and apparatus. They are also continuing the study of the various economic phases of signaling and related activity, in order to place before the signal engineer and operating officer the information necessary in planning new installations, determining whether or not these are economically feasible and analyzing existing installations in order to determine whether or not improvements may be made. Other activities of the committees are the revision of the various chapters of the publication Railway Signaling Principles and Practices, which are published and distributed by the Section and which are used in large quantities by the railroads for the purpose of educating their employees.

Progress in Development of Interlocking

The history of signaling has shown that signal engineers have been prompt to take advantage of any new developments in scientific or industrial progress. The first installations of interlocking were hand operated; then, as other forms of power, such as compressed air, both alone and electrically controlled, became available, these were used; then the development of the small electric motor made the operation of both switches and signals more flexible; and, finally, the development of the concentrated filament lamp made obsolete the motor-operated signal with its multiplicity of moving parts, while the motors or compressed air still remain the medium for operating switches.

In the same manner, the application of the principles of electronics is being made by the signal engineer. It has been demonstrated that by the use of carrier and radio systems no limit is placed on the distance between switches and signals and the points controlled or at which indications are received. This has removed any barrier which may have existed to the centralization of operation and in some instances advantage has been and is being taken of it in order to locate control machines at division points not directly adjacent to the territory so controlled. Through the medium of carrier equipment greater use is being made of metallic circuits, with a consequent decrease of materials necessary and a reduction in costs of installation. At the present time, a single pair of wires is being used to control circuits for several districts of CTC, in addition to voice and carrier telephone and teletype circuits, and the use of the higher carrier frequencies is being studied in order to take further advantage of this feature.

Advantage is also being taken of these principles to effect economies, such as the elimination of large batteries and the automatic control of battery charging. The Electronics Committee of the Section is keeping abreast of developments of this nature and reporting to the Section and is also preparing information of an educational nature which is being published and distributed by the Section.

All-Relay Type of Interlocking

A survey of the signaling installations during the past year shows the continuing use of the all-relay type of interlocking where it can be successfully installed. This, however, does not mean that the older types of interlocking using mechanical locking are obsolete, for each has its place, and, when a new installation is proposed, a close study of a particular situation should be made in order to select the most effective and economical type. The advantage of modern methods of switch and signal control gives the signal engineer and operating man an opportunity to consolidate interlockings which are great distances apart, thereby increasing efficiency and effecting large economies in operation.

In the past, the greatest amount of attention of the signal department has been given to the signaling of main tracks and interlocking of main track switches, which is as it should be, as there was the primary need for such improvement. However, more attention is now being paid to yard operations. The use of car retarders has steadily increased, together with power operated switches for pull-in tracks, and there is a broad field for the use of signal apparatus within yard limits to safely increase the speed of train movement entering and leaving yards and to effect economies in yard operation.

In addition to the changes made necessary by improvement in operation, the modernization of signal systems is continuing, and while it will be a great many years before the motor operated semaphore signals will be eliminated, a great deal of progress is being made each year in this direction.

Much may be said about the use of automatic signals for purposes for which they were not originally installed. One of the principal uses is in connection with fences for the detection of slides in mountainous territory and the protection against washed out or burned out bridges. The use of these devices on a large scale effects considerable economies, in addition to providing continuous service at points where only temporary service is maintained in times of greatest danger.

As you may know, the ICC in Docket 29543 on June 19, 1946, issued an order to the effect that all sections of the railroads on which passenger trains were operated at a speed of 60 mph. and freight trains at 50 mph. or more should be equipped with some form of block system, and, further, that where such speeds were 80 mph. they

should be equipped with some form of automatic stop or cab signals. A number of railroads have filed petitions with the Commission for modification of this order and hearings on some of these petitions have been held, but as yet no decisions have been handed down.

Too much credit cannot be given to the signal supply industry in cooperating with the railroads in working out their problems in the signal field and in developing apparatus to meet these problems. I believe the same situation exists in your own field, and the assistance of this industry to the railroads, both in research and the application of principles and of apparatus, is invaluable.

Closer Cooperation Needed

The work of the signal engineer is closely associated at many points with that of the members of this association, and the successful operation of signal appliances is increased to a large extent by the improvement of those portions of the track structure, such as rail and fastenings, switches, and fittings, ballast and drainage, which you install and maintain. Also, a closer relationship between the departments in the design of track layouts and other features wherein both departments are interested should be maintained in order that the highest efficiency may be secured.

In conclusion, I wish to advocate a closer relationship between the two departments, to the end that both may contribute more to improved operation and better functioning of the entire railroad plant, in order that the railroads may better perform their service to the public in providing the most efficient mass transportation, which is the final purpose of the industry.

President Chinn: Thank you, Mr. Beoddy, for a very excellent report. I think we can all agree that no innovation on the railroads did so much to speed up traffic, increase the density of traffic and increase safety at the same time as did signaling. We look forward with interest to further advances.

We will now hear from Mr. K. H. Gordon, chairman of the Electrical Section, Engineering Division. Mr. Gordon is assistant electrical engineer of the Pennsylvania Railroad. Will Mr. Gordon please come forward?

Address of K. H. Gordon

Chairman, Electrical Section, AAR, Philadelphia, Pa.

I thank you for this opportunity to bring you the greetings of the Electrical Section of the Engineering Division and to tell you something of the part that electricity is playing in the work and the lives of all of us.

In his address at the annual meeting of our Section last fall, your president, Mr. Chinn, spoke of how dire would be the consequences if we were suddenly to be deprived of all of our electricity. He said in part ". . . we would be completely in the dark, literally and actually. Electricity is so important in our lives today that it seems to me it ought to be classed next in value to air and water, food, shelter, and transportation. In our complex civilization we simply could not live without it."

The electrical generating industry reached an all time high during the year just past. The installed generating capacity in utility and government-owned plants at the end of the year was 51,647,000 kw., or about 69,300,000 hp., and the energy generated during 1947 amounted to over 255 billion kilowatt-hours. That gives an idea of the

amount of power and energy required to satisfy a part of our needs for electricity. I say a part, because the electricity used, for example, to light our trains or to move our Diesel-electric locomotives, is not included. At the end of the year, the railroads had on hand or on order some 11,300,000 hp. of Diesel-electric motive power. That is a sizeable proportion of the 69 million horsepower capacity of the power industry. Further, the generators carried on passenger cars to supply the lighting and air conditioning load amount to a considerable total. In addition, there are in service something over three million horsepower of electric motive power and nearly two million horsepower of miscellaneous electrical apparatus on the railroads. It is quite evident that this industry of ours is one of the largest users and producers of electricity.

One of the interesting recent developments is the new steam turbine-electric locomotive recently acquired by the Chesapeake & Ohio. It has electric drive similar to that of the Diesel-electric locomotive, the essential difference being that the power plant consists of a steam boiler and turbine instead of a Diesel engine, and it uses coal for fuel. There is also under development the gas turbine locomotive which will, no doubt, use an electric drive.

Some of the comparatively recent developments in electrical devices and methods may be of interest to you even though some of those I will mention may seem far removed from railroad practice.

Control of Lift Bridges

One of these which will be of particular interest to some of you is an exceedingly accurate control for lift bridges. This control, which was installed on a highway bridge over the Passaic River in New Jersey, by using such devices as selsyns and amplidynes, provides means for accurately measuring and correcting skew so that the span is automatically kept in almost perfect alinement. It is said that a skew of ½ in. in a 222-ft. span is the maximum the device will permit.

The use of more and better electric light is growing. Many of the newer passenger cars are lighted almost entirely with fluorescent lamps. And the value of more light in shops and enginehouses is becoming more apparent. Our Committee on Illumination reported last year on an installation in an enginehouse where the connected load per stall amounted to 6.24 kw., whereas one kilowatt used to be considered ample. It was reported that the increased cost of electricity was considerably more than offset by the improved production and morale of the workers and the detection of defects which might go unnoticed under inadequate light.

High frequency heating is finding a much wider use. It is used in many industrial processes such as the heat treating of metals, the manufacture of plywood, and in other places where accuracy of control is of paramount importance. It is even being used in cooking, in the so-called electronic oven. This was described to our Section last fall in a most interesting talk on electronics. The speaker stated that a thick steak could be thoroughly cooked in about 10 sec., but that biscuits would take a lot longer; they would take 25 sec. He added, however, that if the appearance to which we are accustomed was desired, it would be necessary to get a sun lamp and give the steak or the biscuits a coat of tan.

The use of infra-red heating is gaining wide popularity for such tasks as drying paint, textiles, and blueprints, and for drying and baking armatures and field coils in electric manufacturing and repair shops. With this method no expensive furnace is necessary as the air surrounding the article need not be heated. The heating is done by direct radiation rather than by convection which permits considerably lower temperatures than in conventional furnaces.

The Heat Pump

And, while we are on the subject of heating, the so-called heat pump, or reverse-cycle air conditioning offers considerable promise as a means of heating homes and other buildings electrically. This device literally pumps heat from outside into the building just as an air-conditioning unit pumps heat from a room or a car to the outside air. In fact, it is the same type of device as an air-conditioning unit and may be used for both heating and cooling by simply reversing the cycle. It is most readily installed where there is an abundant and inexpensive water supply to serve as a source of heat in winter. However, installations have been made in which the earth under and surrounding the house are used as a source of heat. Efficiencies as high as 300 percent have been realized; that is, for each B.t.u. input in the form of electrical energy, three B.t.u. can be liberated in the building.

An interesting development in the printing industry is an electronic means of maintaining register, or precise superposition of successive colors in color printing. This is done by two photo-electric tubes which constantly compare the speed of the printing cylinders with the speed of the paper and set up the impulses required to correct any discrepancy. Accuracy to within 0.003 in. is maintained. This is far removed from track and structures perhaps, but it does contribute to attractive and successful railroad advertising.

Automatic Temperature Control

During the war it was necessary to develop an automatic control of the temperature of airplane motors as the pilots of combat planes obviously had little time to devote to manual control. Weight had to be kept to a minimum, the vibration problem was terrific, and cowl flap openings for cooling air had to be kept to a minimum to reduce drag on the plane. The problem was given to one of the large electrical manufacturing companies. The device they developed consisted essentially of two parts; a temperature detecting element and a sensitive relay. The detecting element was interesting as it consisted of a material having an unusual characteristic. The normal conducting material gradually increases in electrical resistance with increased temperature. This material decreases in resistance very rapidly as temperature increases. The effect is so marked and the range so wide that the result is practically the equivalent of a switch with no moving parts. The relay was also remarkable, since it was about 100 times as sensitive as any relay previously available and yet was sufficiently rugged to withstand the severe vibration as well as an acceleration of 10 times gravity. Such a device might well find a place on the railroads for some such application as a hot box detector, or for measuring the temperature of rails under a moving train.

Perhaps one of the most remarkable of the war-time electrical developments was the proximity fuse, which was described to us by the speaker on electronics at our meeting last fall. It consists of a miniature radio broadcasting and receiving set installed in the nose of the shell. The set would start to broadcast as soon as the shell was fired and when within about a 100 ft. of the target the impulses would be reflected and picked up by the receiving set; the shell would explode and the enemy plane would be blown out of the sky. We were told that prior to the advent of this device, the most accurate method of firing was able to effect only about one hit per 1000 shells fired. With this fuse the hits were increased to 87 out of 100 shots; quite an improvement to say the least. I have no doubt that even this strictly war development could be adapted to railroad use, should necessity arise. One application, I can imagine, would be the remote warning of track gangs of an approaching train.

By this time, you have no doubt concluded that I could talk on indefinitely along these lines and that there is some danger of my doing so, but I assure you I shall not. The problems which can be solved and the jobs which can be done electrically are many and varied. If your Association has problems with which you think the Electrical Section can help you, we shall be more than glad to have you pass them on to us.

President Chinn: Thank you, Mr. Gordon, for a very interesting discussion. I have often been intrigued with the thought, if a railroad would suddenly lose the use of electricity in every device and machine, what would happen. Its communications, its signaling, its machinery, its bridges, its motor cars, its diesel engines would all be stationary. Electricity is playing an ever greater and more important part in railroading.

Address of Clark Hungerford

President, St. Louis-San Francisco Railway, St. Louis, Mo.
Presented at the Annual Luncheon on March 17, 1948

I am sincere when I say it is a real pleasure and a privilege for me to be here today, not only as a member of the American Railway Engineering Association but also as one of the speakers at your annual meeting. I have been complimented by Mr. Chinn's kind invitation to address you, because I know it is a great distinction to talk before your organization. This is one of the nation's outstanding railroad organizations—a scientific organization that has contributed and is contributing so much to the betterment of rail transportation in this country.

When a railroad man is asked to speak before a group such as this, the natural implication is that he will talk about railroads. There is no subject about which I would rather speak. Therefore, I should like to talk with you for a few minutes about a matter of current concern—the improvement of rail transportation.

This spring marks the 25th anniversary of what to my mind was the most forward and constructive step ever taken by the American railroads. It was a step that was important to the railroads and the nation then, and is important and significant to us today and to the future of the industry of which we are a part. It was a step that was largely responsible for the ability of the railroads to do their job during the recent war and to handle a record-breaking peacetime traffic now under trying conditions.

The Transportation Crisis of 1923

I think most of us here today remember the events of 25 years ago. At that time, I was a bridge inspector on the Southern Railway System and served under the supervision of your distinguished past president, James B. Akers. My main concern in those days had to do with the engineering aspect of railroading, but I did take more than passing notice of what the railroads were doing in the spring of 1923 to meet current transportation demands and at the same time plan for the years ahead.

I didn't realize then the full significance of what the railroads had set out to accomplish. Certainly I never dreamed of the tremendous strides in railroads and railroading that were to result, and I doubt that many people did.

The situation in which the railroads found themselves after the First World War was similar in many respects to that today. During the First World War, there was

difficulty in getting materials and manpower for adequate and proper maintenance of the railroad plant and facilities, although the difficulties then were not so extensive nor so severe as during the recent war. But the railroad plant did take a beating during the First World War, and came out of the war with a great need for rehabilitation and improvement.

In 1923, this country was faced with what Railway Age at the time so aptly called "a transportation crisis." In 1921, we had a depression, and railroad traffic, which had reached unprecedented heights during the war and immediately thereafter, dropped sharply. As a result, the railroads, in spite of their rundown condition, were able to meet all demands and had a substantial surplus of freight cars. But in 1922, freight traffic started upward, and the railroads found it difficult to move currently all the business offered them. Indeed, in the fall of that year, the average daily shortage of freight cars for one week was as high as 179,239—or four times the maximum daily shortage since the end of the recent war.

The Railroads Acted Promptly

In the early part of 1923, freight traffic continued to climb, and there was every indication that it would reach record-breaking proportions. It was obvious that something had to be done to meet the situation. The railroads acted—and acted promptly.

They acted at a meeting of the American Railway Association and the Association of Railway Executives, which since have merged into the Association of American Railroads. The meeting was held in New York City on April 5, 1923, and its purpose was to consider and approve an extensive program "to further improve transportation conditions and to make the best practicable provision to meet transportation requirements as they develop."

At that meeting, the railroads did several things. First and foremost, they announced the authorization of the expenditure of 1100 million dollars for the year 1923 for new and better cars and locomotives and for trackage and other facilities. The purpose of this, of course, was to improve the railroad plant in every way possible, and the appropriation was by far the greatest amount that the railroads had spent in any one year before then for additions and betterments.

Another thing the railroads did to make more serviceable equipment available was to pledge a drastic reduction in the number of bad-order cars and locomotives. They promised to reduce freight cars awaiting repairs to 5 per cent of the total ownership, and reduce locomotives awaiting repairs to 15 per cent. At the time, some people believed that these goals were impossible to reach, but they were reached. In the case of locomotives, the railroads even exceeded their goal.

Another part of the improvement program—and a most important part—was directed toward getting more effective use out of the railroad plant after it had been improved. This was to be the joint responsibility of the railroads and those who use them. The movement to obtain organized shipper-receiver cooperation was already underway when the railroad executives met in New York City, but it was a very definite part of the improvement program. In January 1923, the Northwest Shippers Advisory Board was organized, and this was the beginning of the regional Shippers Advisory Boards and the national association of those boards. We know now that if it had not been for these shipper organizations and the splendid work they did, the improvement program launched by the railroads in the spring of 1923 could not possibly have been as effective as it was.

The improvement program had an immediate and long-range effect. As a result of the huge investment in improved plant and facilities—more than 13½ billion dollars

from 1923 through 1947—the railroads have been able to meet one transportation emergency after another as it developed. Most important of all, they were able to meet again the supreme test of war by turning in the greatest transportation performance in history. Moreover, thanks to better railroads which resulted from investment in better facilities, they are able today to handle great tides of commercial traffic in spite of difficulties of all sorts.

You can well imagine what might have befallen this nation if railroad management had failed to act as it did in 1923, and also if the users of rail transportation had not banded together to promote and maintain adequate transportation service and car supply.

I believe everyone will agree that the railroads are doing a far better job today than they did in 1922. And they are doing it with 550,000 fewer freight cars, 16,000 fewer passenger cars and 22,000 fewer locomotives than they had then. The reason they are doing so much more with so much less is that today's railroads are better in every way.

At the present time, the railroads are operating at peak efficiency. They are setting efficiency records that in 1923 would have been considered unattainable. As a consequence, the output of transportation for each hour that the average freight train is on the road was 133 percent greater in 1947 than it was in 1923. This shows more clearly than anything else what real progress has been made by the railroads in the last quarter of a century. It shows the results of continuous investment in better railroads and railroading.

In Somewhat the Same Position Today

As I have already said, the railroads find themselves in somewhat the same position today as they were 25 years ago. They have a plant which has undergone the greatest wear and tear in history. Consequently, there is a great need for more and better equipment, and there is also a need for maintenance and repair work which has not been done because of inability to get materials and labor. In short, if the railroads are to meet current and future demands satisfactorily, they must continue and expand the improvement program started in 1923.

The railroads have set out to do this. They are spending or preparing to spend hundreds of millions of dollars for new and better equipment and for improvements in their roadways and structures. In fact, there is every reason to believe that their capital expenditures for additions and betterments this year will reach, if not exceed, the level of such investment just before the last depression. For instance, at the present time, they have on order approximately one billion dollars' worth of new rolling stock.

How soon we will feel the effects of the present improvement program depends largely on the ability of the carbuilders and the locomotive manufacturers to fill orders. The railroads now have on order about 120,000 freight cars and approximately 2500 passenger cars. At the present rate of production, it will take the carbuilders more than a year to turn out the number of freight cars now on order and about two years to produce the number of passenger-train cars on order.

The railroads began ordering large quantities of new equipment as soon as the war was over, but delayed delivery has made it impossible for them to provide at all times and in all places the kind of service that people have come to expect and the railroads want to give. This has been particularly true of the passenger service, which in recent months has been the subject of a great deal of comment, some of it unfavorable.

This is a matter of real concern to the railroads, and should be of concern to everyone identified with them. We must not forget that most people form their impressions

of railroads by what happens on the passenger trains and in the passenger stations. This is true because relatively few people ever ship or receive a package by freight, but the great majority of people do take a train trip at one time or another.

Nobody would say that today's passenger service is all it should be, or all that the railroads would like to have it. In fact, there will always be opportunity for improvement. But we can say, and say with pride, that passenger service is moving in the right direction. It is much better now than it was during the war, and it will be still better in the future.

One of the principal passenger service problems now confronting the railroads is the heavy demand for room accommodations in sleeping cars. At the present time, this demand exceeds the supply. More than 1000 new room-type sleeping cars have been ordered since the end of the war, and their delivery is just now getting well underway. As these cars, as well as the new coaches, diners and lounge cars, are turned out in greater numbers, the railroads will be on their way toward making the supply of accommodations more nearly equal to the demand for them.

Shortages Lead to Difficulties

But, until then, there will continue to be the sort of difficulties that surround the sale of every article or service which is in short supply. Consequently, there will be complaints about the handling of reservations and ticket sales, and there will be rumors and reports of black markets.

Now and then we hear that there is something wrong with a reservation system which results in trains operating with empty space which had been reported as sold out. The present system is not perfect, but it is constantly being revised and improved. Such situations as I have just mentioned are due either to late cancellations or to the fact, very often overlooked, that trains do not serve only their terminal cities. They also must serve intermediate points, so that they usually leave from or arrive at their terminals with space which appears to be unsold but is for the use of passengers to and from intermediate stations.

I would like to say a word or two about the rumors and reports of a black market in reservations. No matter how large or how small a black market there is, the railroads, with the help of the public authorities, are doing everything they can to stamp it out. Those who blame the railroads for whatever black market operations there may be in railroad accommodations should bear one thing in mind: a railroad is a common carrier, and as such, it cannot refuse to sell its services to any and all.

There is another thing that I think should be taken into consideration in any discussion of the present passenger situation. While it is true that railroad passenger traffic has dropped considerably since the war, it is still double what it was just before the war. And remember, too: The railroads are handling this traffic with about the same number of passenger-train cars as they had in 1939.

The railroads are doing everything they can to improve their passenger service. They are doing this not only through the purchase of new and better equipment, but also through the less tangible but equally important task of raising the standards of performance all along the line. They have added new trains, shortened schedules and improved stations, and more of all these things are coming as soon as materials and labor shortages are overcome. The railroads have also undertaken training programs for passenger-service employees, and they have sought to improve their reservation and other service procedures.

Yes, the railroads are doing everything in their power to put themselves in a position to handle more business and handle it more efficiently. But their problem in this

connection is not limited to increasing their capacity and bettering their service. There is also the problem of obtaining sufficient revenues to make ends meet and produce such earnings as will warrant further investment in improvements.

Adequate revenues can be obtained in only two ways. First of all, there must be a sufficient volume of business for the railroads to handle. Secondly, and equally important, the traffic must be moved at rates which are compensatory.

Since the end of the war, railroad traffic has been at peak peacetime levels. But revenues have not kept pace with wage increases paid railroad employees and the higher prices of the things which the railroads buy. As a result, there has not been a balance between what the railroads take in and what they pay out.

The reason for the inadequate revenues should be obvious. Although the cost of other things has gone up tremendously, railroad rates, comparatively speaking, have gone up only slightly. That is why the railroads are now before the Interstate Commerce Commission for authority to increase their freight rates.

As you know, the commission granted two successive interim increases last fall to meet a critical situation. The final decision has been reserved until after study of the voluminous record in the case. What the commission will finally decide is anyone's guess, but from the grasp of realities which that distinguished body has shown in its interim decisions, I feel confident that the outcome will give recognition to the revenue needs of the railroads, as well as to the necessities of commerce.

It is in this faith that the railroads are going ahead with their plans for improvement. It is the same sort of faith that the railroads had in 1923 when they embarked on their rehabilitation program. That program has paid off many times, and everybody has benefited from it. The modernization program now underway will also pay off. It will enable the railroads to meet peacetime demands satisfactorily, and also be prepared to meet the heavy and difficult demands which would develop in the event of another war.

Today, all of us are very much concerned about this nation's security. It was only a little more than an hour ago that the President of the United States, in discussing the present international situation, painted a grim picture and warned Congress and the people that the situation in Europe is critical.

Our Railroads Must Be Strong

None of us want war, but if a national emergency should arise, this country will find it necessary to turn to the railroads just as it did in the last war. Will our railroads be ready? They are ready today, because our railroads are always in a state of national defense. Since war broke in Europe in 1939, they have met one test after another, and they can be relied upon to do it again.

But I would like to repeat something I said a few minutes ago. If our railroads are to be able to carry all future loads that may be placed upon them, they must be permitted *now* to obtain the materials even if it means that all of us must go a little while longer without some of the things we would like to have.

Let there be no mistake about the role of our railroads in the future. Let there be no mistake about how much America's future depends on the railroads. And let us never make the mistake of doing anything that will weaken our railroads.

We need physically and financially strong railroads today more than ever before. We cannot afford to take a chance on anything less. Given the materials they must have now, and the revenues they need to go on with their great program of improvement, they will provide this nation with the kind of transportation service it must have and the railroads want to give.

Report of the Tellers

Presented Wednesday Noon March 17, 1948

We, the Committee of Tellers, appointed to canvass the ballots for officers and for members of the nominating committee, find that the count of the ballots is as follows:

For President

C. H. Mottier 1126

*For Vice-President**

G. L. Sitton 1118

For Directors (Three to be elected)

E. C. Vandenburgh 480
C. G. Grove 461
R. L. Groover 418
Clark Hungerford 379
W. J. Hedley 352
R. J. Gammie 347
G. W. Miller 340
F. J. Bishop 310
P. O. Ferris 310

For Nominating Committee (Five to be elected)

I. H. Schram 788
E. J. Brown 710
E. E. Mayo 704
W. L. Young 612
M. H. Dick 603
C. J. Henry 585
E. S. Birkenwald 494
W. T. Alexander 424
R. W. Marye 319
C. S. Burt 314

Respectfully submitted,

The Committee of Tellers.

R. C. Bardwell, *Chairman*
A. R. Wilson
J. E. Teal
F. G. Campbell
H. F. King
F. D. Danford
H. E. Graham
H. L. McMullin
A. G. Rankin
O. E. Mace
R. M. Stimmel
J. E. Fanning
D. C. Teal
R. E. Warden
G. E. Martin
G. F. Metzdorf
H. F. Whitmore
H. E. Silcox
R. E. Dove
E. M. Grime
S. H. Poore

* Under the provisions of the Constitution, F. S. Schwinn, advances from junior vice-president to senior vice-president.

Installation of Officers, March 18, 1948

President Chinn: We will now interrupt the presentation of the committee reports for the purpose of installing the new officers. However, before proceeding with this formality, I would like to inquire if there is any other business to come before the meeting.

Past-President Hastings: Mr. President, ladies and gentlemen: Strange is our situation here upon earth. Each of us comes for a short visit, not knowing why, and yet sometimes seeming to divine purpose.

Why did I say that? Bcause I seem to divine a purpose in my appearance here before you just at this moment. Not trying to be funny, I know just exactly how President Chinn feels just at this moment.

"The first requisite, President Chinn, of a good citizen in this great republic of ours is that he shall be able and willing to pull his weight; that he shall not be a mere passenger but shall do his share in the work that each generation of us finds ready at hand; furthermore, that in doing his work he shall show not only the capacity for sturdy self-help but also a self-respecting regard for the rights of others."

That, which you noticed I just read, as I seldom do, is not a statement of your friend Hastings, sir, but it is something I clipped from a paper sometime ago—a quotation from a statement that was made at some length by the late Theodore Roosevelt.

You know, it has long been a custom in this great Association of ours to present a plaque to the president the closing day of our annual meeting, and I have certainly been privileged to have far more than my share in these presentations. But I am particularly honored this morning in being able to be here and to present this plaque to President Armstrong Chinn.

Through the years you have been pulling your load; and since you have come into the highest office in this Association, in the gift of its membership, you have not only performed magnificently a service for the Association through this past year but you have also, even more greatly, endeared yourself to us.

This plaque records its grateful appreciation to Armstrong Chinn for his able administration of the affairs of the Association during his term as president 1947–1948.

I am sure, Mr. Chinn, that in the years that are ahead of you—and God grant that they may be many—as you look at this each day, I hope, it will be an inspiration to you, because it not only is a token of the esteem that this Association holds for you but it should carry with it the feeling for you, that as each time you read it you realize the fact that along with this piece of wood and this magnificent engraving there is a perfect halo of love and of affection and of regard and of respect for a man who has so splendidly performed his service for this Association.

And may I also say to you, that, knowing you as I do, as well as I do, and through the years that I have known you, you not only have performed service for the Association, but in your daily living and in your daily contacts with man, you have been an inspiration to many, and I am sure in the days of the future you will inspire many, many more.

God bless you! (Applause)

(Presentation of plaque)

President Chinn: Thank you, Mr. Hastings. There are times and occasions that come into the lives of most men that they treasure and want to remember always.

My year as president of the AREA is one of those occasions for me. I have enjoyed it, and all that it has brought me, more than I can tell you.

I am very happy to receive this plaque and will keep it as a constant reminder of a very happy period in my life.

I will now ask Past Presidents Akers and Miller to escort President-Elect Mottier to the rostrum.

(President-Elect Mottier was escorted to the rostrum.)

President Chinn: I would also like to have Vice-President-Elect Sitton come to the platform so that those in the Association may see the man who is being trained to become president two years hence.

Mr. Mottier, it is with a great deal of personal satisfaction that I turn over to you this gavel representing the authority of the office you are now assuming. You have been chosen by your fellow members because of your outstanding qualities of leadership and ability you have so well demonstrated. They made no mistake.

You are assuming the leadership of this Association during what will be a memorable year, the Association's fiftieth year of service.

With conditions in the world such as they are, we never know at what moment our railroads may again be asked to carry a tremendous traffic load. During such times our Association needs a strong leader.

Mr. Mottier, I know that you will discharge your responsibility with honor to the Association and distinction to yourself. You have my best wishes for a most successful year. (Applause)

(President Mottier assumed the chair.)

President Mottier: Mr. Past President (laughter), members, guests and friends of the Association—that includes the ladies as our guests and friends: I look upon you as the rooting section in the bleachers. (Laughter) I know Mr. Chinn and I both appreciate your presence.

Friends, I am deeply and humbly grateful for the confidence you have shown in selecting me as president of our Association, and I hope that none of you will ever have occasion to be disappointed in the selection. I will not expect quite as much oratory at my retirement next year as Mr. Chinn received.

I fully recognize the responsibility which now rests on me, particularly when I think of the long list of illustrious men who have preceeded me in this position and under whose guidance our Association has reached a position of unchallenged leadership in its field.

I am sure that the AAR will continue to give us its full support. I have confidence in our Board of Direction, in our secretary and his staff, in our research organization, and in the chairmen of our committees and subcommittees and in our membership.

I solicit your help and your cooperation, and I know that I will receive them. It is because of the confidence that I have in you and my knowledge of the loyalty that you have for our Association that I have no fear as to the success of our mutual efforts. I also fully realize the opportunity for service which this position affords, and, within the limit of my ability, I acknowledge and accept that responsibility. It will

give me an opportunity to pay back to the Association some of the debt that I owe for the good that I have received from it.

In this connection, I would like to emphasize a thing that I feel very keenly. One of the vital functions of this Association is the development of men, and in this field many of you can play an important part by encouraging our younger members to read the proceedings, attend the meetings, and take part in committee activities.

If you will pardon a personal reference, I would like to illustrate what I have in mind and show how you older men—I should say *we* older men—and those in authority on our railroads can use this Association to help develop our younger men.

I joined this Association in 1919. In 1920 I was made office engineer under Mr. Brumley as chief engineer and Mr. Baldwin as vice-president. I am sure many of you men here know those two men. They were both enthusiastic supporters of the AREA. Mr. Baldwin was a past-president and Mr. Brumley later became president.

I recall how they talked to me about joining the Association, and how they encouraged me. The first year following my appointment as office engineer, I assisted in the preparation of a subcommittee report on warehouses. As a matter of fact, I wrote the report. They gave me every encouragement and help. And as a result of that report, and again at their suggestion and through their influence, I was appointed chairman of a subcommittee and assigned the subject of passenger terminals. I admit that one reason why they did this was because we were interested in the subject. That year I spent a tremendous amount of time in the preparation of that report. They gave me every encouragement and all the help that I needed.

We presented that report to the convention in March 1923, and, if my arithmetic is correct, that was 25 years ago, a quarter of a century. Yet I recall very clearly the reception I received, the encouragement they gave me, and the number of older men who came to me afterwards and thanked me for the work that I did.

That was a long time ago, but I remember several of those men today, and the conversation. It made a profound impression on me. I remember Mr. Lee of the Western Indiana who was a past-president. I remember Mr. Campbell, who many of you men here know, who later became president of this Association. He never passed up an opportunity to speak to me and to encourage me, and I know from what other men have said he did the same thing to them.

The point I am trying to make is that, without the encouragement and help that was given to me by my superiors and the older men in this Association, I would not be standing here as your president this morning. I want to give that as my personal testimony, and to urge that you give the men in your organization an opportunity to show what they can do, help them to do it. Some of those young men will surprise you, and we will be doing them a real service.

I understand that at this time it is my privilege to introduce our new officers but, before doing so, I wish to pay a word of tribute and to thank our retiring directors, Messrs. Bates, Oviatt and R. E. Dougherty.

Mr. Dougherty is now president of the American Society of Civil Engineers, which is a signal honor and by most civil engineers is considered the highest honor that can come to a civil engineer in this country.

We also have one of our past-presidents, Mr. E. M. Hastings, the silver-tongued orator from Virginia (laughter) who leaves our board. We are sorry to see him go. We want to thank him for the many years of service that he has given our Association.

Mr. Hastings has been on our board, due to a combination of circumstances, for 14 years, a period of service that has been exceeded by only one other individual in the first 49 years of the life of this Association.

Most of you also know that Mr. Hastings last year was president of the American Society of Civil Engineers. He preceded Mr. Dougherty. To have two members of our Association in succession, presidents of the ASCE and, at the same time, as members of this board is a thing that has never before happened or occurred in the 96 years of the life of the American Society of Civil Engineers, and it is pretty safe to say it will never occur again.

We are losing two oustanding men from our board this year.

Mr. Hastings, you wouldn't object to standing and taking a bow, would you? (Applause)

I suppose all of you know that Mr. Schwinn, assistant chief engineer of the Missouri Pacific Lines, Houston, who was junior vice-president is automatically advanced to the position of senior vice-president.

Mr. Schwinn, I don't know why they left you out there in the audience all alone. Suppose you stand up and take a bow. (Applause)

Mr. G. L. Sitton, assistant chief engineer of the Southern Railway System, becomes our junior vice-president, and all of you who know him will gladly welcome him to our board.

Mr. Sitton, suppose you stand up and take a bow. (Applause)

You have selected three new directors. I will call their names and, as I do so, will each of them stand and look real pleasant and intelligent (laughter) and then sit down

I have been interrupted.

Past-President Chinn: I just want to interrupt to say that I have got to leave for home immediately, because I was just advised over the telephone that three of our organizations, the trainmen, enginemen and firemen are going out on strike tomorrow morning at ten o'clock, because they don't like the award they got from the railroad adjustment board. So, I have to get home. (Applause)

President Mottier: Our best wishes go with you, Armstrong.

Mr. E. C. Vandenburg, chief engineer of the Chicago & North Western Railway, is one of our new directors. Please stand, Mr. Vandenburgh. (Applause)

Mr. C. G. Grove, chief engineer maintenance of way, Western Region, Pennsylvania Railroad. Mr. Grove! (Applause)

Mr. R. L. Groover, chief engineer of the Atlantic Coast Line. Mr. Groover! (Applause)

That concludes the interruption in our program.

Presentation and Discussion of Committee Reports

Discussion on Economics of Railway Location and Operation

(For Report, see pp. 1–62.)

(President Chinn presiding)

Chairman F. N. Nye (New York Central): During the year just past, Committee 16—Economics of Railway Location and Operation has considered eight subjects. Progress reports are made on four of them, and one is concluded with a final report. The subcommittees assigned to other subjects have made progress on their respective studies but at this time have no report to present to the convention.

The report on Assignment 1—Revision of Manual—will be presented by the chairman of that subcommittee, Mr. E. E. Kimball.

E. E. Kimball (Schenectady, N. Y.): The committee has no report for inclusion in the Manual but desires to make a statement of plans and present as information an exhibit for future reference to be noted in the Manual.

Last year a plan was agreed upon for collaborating with the Mechanical Division of the AAR in regard to revising Section 11 which is devoted to "Power" in order to develop a method for computing locomotive characteristics which will meet as near as possible the needs of the Mechanical and Engineering divisions. A report is expected for next year.

The material in Section I, Economics of Railway Location, is being reviewed and any changes that are recommended will be reported next year.

The following is a brief discussion of this year's report:

Section 16 of the Manual is the work of two committees—Economics of Railway Location and Economics of Railway Operation—which have been consolidated. The two parts are more or less distinct and disconnected.

Last year's report was primarily intended to tie the two parts together and was offered as information until the subject could be given more consideration and the principles involved tested in practice. This year's report shows examples of the application of the theory and principles of train performance in order to test the validity of the method and to explain the significance of certain operating statistics.

In some cases it is necessary to accumulate experimental data before the theory can be applied. A search is being made for sources where such data can be obtained. When they are made available, it is proposed to work up similar exhibits for reference and information.

President Chinn: Mr. Kimball, your report will be accepted as information. Thank you.

Chairman Nye: The report on Assignment 3—Methods or formulas for the solution of special problems relating to more economical and efficient railway operation—will be presented by the chairman of that subcommittee, Mr. B. T. Anderson.

B. T. Anderson (Union Switch & Signal Company): The report is based on the renaissance of the Chicago, Indianapolis & Louisville Railway. This railway, familiarly known as the "Monon," operates a 541-mile single-track main line from Chicago to Indianapolis, Ind., and Louisville, and branch lines to Michigan City, Midland and French Lick.

Since the Monon was reorganized on May 1, 1946, the new management has undertaken an ambitious improvement program for rebuilding and modernizing its entire plant which will make it one of the more completely mechanized railroads in the United States.

This introductory report outlines some of the aspects of the proposed program for the years 1947, 1948, and 1949 relating to motivepower, equipment, track, signals and communications and was based on data given to Committee 16 up to September 1947. Since that date, some additional interesting information has been made available as follows:

The mileage run by steam locomotives is about half of that run in 1946. The repair cost per locomotive mile in 1947 was about 43 cents per mile as against 44 cents in 1946.

The mileage run by diesel locomotives has increased from 149,000 in 1946 to 1,769,000 in 1947, about 12 times.

The repair cost per locomotive mile on diesel equipment has been reduced from about 21 cents a mile to 18 cents per mile.

The mileage run by all locomotives in 1947 was about 27 percent over that in 1946.

The repair cost of the locomotive miles in 1947 was about 27.5 cents a mile as against 42.8 cents in 1946.

Diesels are hauling 90 percent of the traffic on the total mileage and will be 100 percent in April, following delivery of 8 new locomotives now on order.

Car miles per car day of serviceable freight cars for calendar year 1947 were 52.1 as against 39.0 in 1946, or an increase of 34 percent.

Car loadings for the calendar year 1947 were 16.1 percent heavier than in 1946 and are averaging higher than any time during the war.

Gross ton-miles per train-hour increased from 27,607 in December 1946, to 33,238 in December 1947, an increase of 20 percent, and the gross tons per train increased from 1626 in December 1946 to 1822 in December 1947, or an increase of 12 percent.

There should be delivered in the first quarter of 1948, one 3000-hp. diesel locomotive for road freight service and six 1500-hp. road-switchers for road and switching service. When these diesel locomotives are received, all trains and switch runs will be completely dieselized on the Monon. There are also being delivered in the first quarter of 1948 about 550 freight cars. This will make a total approximate freight car ownership of 2731, which will meet the Monon's AAR ownership requirements.

Freight schedules have been speeded up six hours between Chicago and Louisville. About 40 percent of the Monon's freight is originated on line.

The installation of streamlined trains between Indianapolis and Chicago resulted in an 87.2-percent increase in passenger revenues on that route for December 1947 over December 1946. While the Monon is losing about $10,000 a month on its passenger service, it is hopeful of breaking even this year when new trains go into service between Chicago and Louisville early in the spring of 1948.

The gross revenue in 1947 was about $15,586.376, or nearly $390,000 over the estimated figure shown on page 22 of the committee report. The estimated gross revenue for 1948 is about $19,600,000, or nearly 50 percent over 1944, the peak war year.

Net railway operating income in 1947 was $444,115 as compared with a deficit of $594,944 in 1946.

A comprehensive improvement program of this kind over an entire railway is of unusual interest to the AREA members, and it is hoped that in succeeding reports the committee can state the results of this program on the Monon Railway.

President Chinn: Is there any discussion of this report?

C. E. Johnston (Western Association of Railway Executives): The president invited discussion by the younger members, but I got in here somehow, and I am not up here to criticize this report. I made certain observations, however, and what I say may, in a sense, appear critical but it is intended as constructive criticism and in the interest of this Association.

I think this is one of the most important committees in the Association. I think the problems related to location and operation are probably the most important in the railroad field today, and getting more important as we go along. Therefore, I think this Association has to be very thorough and very careful in its studies and in getting data that will be helpful to other railroads in undertaking to justify expenditures, particularly capital expenditures, when money is so scarce and credit is so questionable.

This report of Assignment 3 I find very interesting. It is good reading. I certainly congratulate the Monon Railway on undertaking such an ambitious program, and I also admire the courage of the management of the railway in its effort to modernize and to mechanize.

The renaissance of the Monon is one thing—the revival, resurrection, rebirth or whatever you wish to call it, but the justification for added capital is another thing. And I am confused, in this work, to separate the two. There is nothing in here that indicates what part of this 26 million dollars to be spent over three years is maintenance, rehabilitation or additional betterment. While 16 million dollars of it is for power and equipment and 10 million dollars is for roadway and other items, signaling, grade reduction, and what-have-you, it makes quite a difference to the members of this Association, in applying the same measuring stick to other railroads, whether it is capital or whether it is maintenance cost. There is quite a difference in their calculation as to the justification for the capital. That is my point.

I think the report is fine, so far as it goes, but it does not go far enough. If what I say here will help get more information on the subject, I think I will have justified the time and effort.

The report says that, since the railroad was organized, the new management has undertaken this ambitious improvement program of rebuilding and modernizing, and in that it enumerates complete dieselization by the end of 1947. Almost all of our railroads are doing the same thing and getting the same results on increased trainload, increased miles, loaded miles per hour, and what-have-you, the same as in this plan. We are all trying to buy new passenger and freight cars. I do not know that it is going to increase our traffic business any. I rather doubt it. Anyhow, it is being done by all.

New and heavier track structure and line changes, we all know about, and I am assuming that we undertake to justify the capital that goes into that improvement. Respacing automatic block signals and adding CTC—I think there, again, you have to justify, and there is nothing in the report as drawn to help any of us justify the installations on other railroads. Improved communication facilities—we are all trying to do that.

The report says they are spending 26 million dollars in the present three-year period, 1947, 1948 and 1949, and may spend an additional 24 million dollars to round out the program. There, again, how will the other railroads, and the other members of this organization, be able to figure whether or not they are justified in doing similar work? There is no formula; there is no estimated economy in the report. That is my point

In the conclusion it says: This program contemplates—improved service to the shippers and traveling public; increased freight and passenger train speeds; heavier train loading—there is an economy; fewer and longer sidings, etc.; improved track

structure and line changes to reduce grades and flatten curves. What is the basis of justification?

Of course, the old school followed Wellington, or very closely, with respect to his economics of railroad location and elimination of curves and reduction of rise and fall, and all those things, and we came up with a figure showing the economies, showing whether or not they were justified. When the work was done, after we were able to get money—and I have been through these rehabilitation programs—then we set about to see how our estimated economies worked out, whether or not we were justified to go ahead and do more of it.

To be of real value to this Association, that is my point exactly, we must have the basis upon which a figure can justify these expenditures. (Applause)

Mr. Anderson: The subcommittee appreciates very much Mr. Johnston's comments, and we have in mind doing exactly that. At the start of our program, of course, in these various improvements, certain estimated figures were set up as a basis of estimate, but we did not feel as if we should get into that picture at this time, until after some of these improvements had been made and results checked, so that the committee could come up with some actual results which we felt would be more valuable than any of the estimated figures. The point is well taken and we certainly, in our succeeding reports, will be very happy to answer Mr. Johnston along that line.

Mr. Johnston: I move that the report be referred back to the committee for more complete information with respect to the estimated economies to be produced by capital expenditures appropriated. Before the Association can benefit from the report, its members should be able to test out similar formulas to determine whether or not such capital expenditures may be justified on other railroads.

(The motion was seconded.)

Chairman Nye: Committee 16 will gladly accept that resolution. As Mr. Anderson said, we are not submitting it as a final report. It is merely a progress report. As a matter of fact, a careful reading of the report will show that we have brought forth no formula in this first installment. We are merely setting forth the problem which confronted the management of this property. The Monon was selected not because it is doing something necessarily different from what other carriers in the country are doing. We rejoice as engineers that all the railroads have forward-looking plans, modernizing their plant, facilities and equipment. The Monon was selected because it was starting from what we might call scratch, and any improvement in their operation, their traffic possibilities and their revenue-producing possibilities could be more directly attributable to the program outlined in these pages.

As Mr. Anderson said or implied, the proof of the pudding is in the eating. As we watch the development of this program, we at that time can take cognizance of the suggestion made in Mr. Johnston's resolution and show how certain fundamental principles have been interpreted by the management and what results came from them.

President Chinn: Mr. Nye, I understand your report is submitted as information. It is the practice of the Association not to vote on reports submitted as information, only on matter that is submitted for inclusion in the Manual.

I assume, Mr. Johnston, that you had in mind the final submission of a formula for handling this kind of work which, if presented, would then be presented as Manual material and acted on by the Association.

Mr. Johnston: My thought in the matter was that the report should go back to the committee because, with the additional information, it is so much more valuable as information to the members of this Association.

President Chinn: I think that is correct, but do you have any objection to the report being published this year as information, with the understanding that the committee will develop the additional information you have in mind for a further report?

Mr. Johnston: That is what I intended to infer. I am perfectly willing to go along with the majority here.

Chairman Nye: The next report is Assignment 5—Electrification and the development of modern power units; their influence on railway economies—and will be presented by the subcommittee chairman, Mr. L. K. Sillcox.

(Vice-President Schwinn presiding)

L. K. Sillcox (New York Air Brake Company): Previous reports of the committee have related to electrification of steam railways and evaluations of straight electric and diesel-electric locomotives. The last previous report of the committee was presented to the 1946 convention and dealt with the diesel-electric, comparing it with the steam locomotive as was done in the case of the straight electric. Our 1946 report contained steam and diesel-electric cost data but in insufficient volume to support any general conclusion.

In 1947 we devoted our entire efforts to verifying cost figures of our original diesel-electric report but we were not wholly able to do so. Our method was the circulation of an economic questionnaire among all roads operating diesel power and having representation on Committee 16. There were 14 such roads and may I take this opportunity to express the appreciation of our committee for the 100 percent cooperation which we enjoyed from the railways approached for assistance. The questionnaire was quite comprehensive, and considerable time and effort were involved in replying to it. However, all responded graciously to our request.

We were of the opinion that data from 14 roads having extensive diesel experience would be ample and that valuable comparisons would result. A condition was encountered however that materially reduced the number of comparisons possible and thus rendered it impossible to draw conclusions that could be presented with confidence. The difficulty to which I refer is the variation in units in which cost data are expressed. For example, repair costs of diesel locomotives in passenger service were reported in locomotive-miles, train-miles, and car-miles; in freight service they were reported in locomotive-miles and 1000 gross ton-miles, while in yard service we received replies expressed in both locomotive-miles and locomotive-hours. Add to this the various horsepower capacities, and we arrive at a maze of data, while not unrelated, of such a character that we are not in position to submit the results of our survey other than as information.

Operating costs and miscellaneous data, such as availability and utilization percentages, number of locomotives, their average ages, and original costs were obtained from the questionnaire, but your committee did not deem the mass of data collected could be used without detailed knowledge of the operating conditions surrounding each case. Therefore, these data were not submitted for publication, and we are holding them in our files with the thought that they will be of use in comparing the effect of age at a later data when more mileage will have been accumulated. We did include in our report data indicating the trend in repair costs with age for the two power types, and this material appears on pages 23 to 25, incl., of our report.

I shall not burden you with a series of statistical statements since there are so many qualifying factors that an oral discussion of the results would be futile. Consider for a

moment the percentage repair cost increase with age of a group of diesel switching locomotives. This immediately involves the following questions: How old are they and how intensively were they utilized in relation to another group with which we are attempting to compare them? Also, how many locomotives were there in the two groups and what were their horsepower ratings? I would recommend that the covering comments in the report be read before any derived values are assumed absolute, in order that a clear understanding of the arbitrary standards assumed in their calculations may be obtained.

As has been true with all steam-diesel data made available to the committee, it is necessary to compare relatively new diesel locomotives with old steam power. However, while there is a discrepancy in the ages of the locomotives, the comparison covers the actual motive power being used by the railways at this time so that a policy may be established and decisions reached based upon the showing made in current practice. It appears to be a more reliable and determinative index than any that could possibly be obtained by estimates.

It is the intention of your committee to prosecute our search further for substantiating data. The problem is too acute to be summarily dismissed. We may not find a solution during 1948 but we feel that as age accumulates, one will be forthcoming. We therefore recommend that the subject be continued, thus providing a more comprehensive basis for decision as to the economic justification of the two power types.

It is the further intent of your committee to consider the oil-burning gas-turbine locomotive in its relation to the diesel-electric and the coal-burning turbine with steam power. Whether we shall have a report this year is problematical but we shall investigate the field.

Vice-President Schwinn: The information that this subcommittee is developing is one of great importance to the industry. We will all look forward to the unfolding of the conclusions. The report is accepted as information.

Chairman Nye: Our next report, on Assignment 6, describes the general course of the cost of railway transportation and operation over the past 100 years, setting forth the principal determining elements and economic significance.

Mr. R. L. Milner, chairman of our subcommittee covering this subject, will present the report.

R. L. Milner (Chesapeake & Ohio): The title of this subject is very broad. It seems limitless. One hundred years is a long period to cover statistically. Although some general data are available as far back as 1840, operating statistics for all railroads are available only as far back as 1890 and 1871.

While this subject might be progressed piecemeal, that is, by developing various costs, such as maintenance of equipment in general or, more specifically, the maintenance of freight engines or only the labor cost thereof, it was decided to treat the cost of railway transportation and operation as a whole, resolve it on a cost per unit based upon the volume of freight and passenger traffic; then to develop and analyze this unit cost in a broad general way. Analysis in another manner might require exhaustive research over an indefinite period and thereby be beyond the intent of the committee.

The unit cost used was based upon total operating expenses and total traffic units. Total traffic units are the sum of revenue ton-miles and three times the total passenger miles.

For the purpose of easy analysis and comparisons, five tables and one chart have been included in the report thus far. Table 1 shows total traffic units and total operating

expenses from 1890 to 1945. These are reduced to traffic unit costs in terms of the current dollar, and also in terms of the dollar of 1926 purchasing power, which is used as the "constant" dollar in the report. This 1926 dollar was considered a fair index and as satisfactory for comparative purposes as more recent indices based on the 1935–39 or the 1941 periods.

The general course of the cost of railway transportation and operation as indicated in terms of cost per 1000 traffic units on the chart, shows an over-all decrease of 44 percent from 1890 to 1945 in terms of the constant (1926) dollar, and an increase of but 20 percent in terms of the current (1945) dollar.

However, the course of the change in unit cost based upon the constant dollar has been irregular. A relationship was noted between unit costs and business and other conditions. From this it was deduced that operating costs per traffic unit are greatly influenced by and, in general, vary inversely but not directly with the volume of traffic; also, that costs generally decreased during periods of national prosperity and increased during periods of national depression; also, that high costs of labor, material, and fuel which generally accompanied or followed war periods, resulted in higher costs per traffic unit, finally reversing the trend toward lower unit costs brought about by the higher traffic volume of such periods.

From this it may be inferred that the railroad industry, in order to control unit costs, must develop high traffic volume. This may be done:

By securing and retaining a high proportion of the passenger and freight traffic requirements of the country;

By aggressively continuing to attract and help locate industry along railroad right-of-way;

By providing traffic incentives or services designed to effect use of railroads to ultimate capacity which during the late war period was demonstrated to be far greater than normal traffic volume.

Besides this, the railroad industry must realize that its own prosperity as reflected by low operating unit costs, can only follow national prosperity, and therefore must contribute in every reasonable manner to it. This is so because national income is a vital factor in the demand for the products of industry and the land, and such demand is reflected in increased freight and passenger traffic.

The principal determining elements of cost of railroad transportation and operation go beyond the item of operating expenses. They include any items which directly or indirectly affect net income, such as taxes, wages, fuel, material and other costs, most of which have increased substantially since 1943.

The tax burden has increased tremendously and disproportionately, thereby stressing the importance to railroads of securing from the governing tax bodies equal and equitable tax treatment along with other transportation agencies. The unfairness of subsidies to competing transportation agencies, both to the railroads and to the public, must be continually stressed.

The investment caliber of railroad securities is seriously lessened by the adverse effect of high taxes, wages, fuel, and material costs upon operating expenses, and thereby upon railroad operating income.

Investment money is necessary in making prudent expenditures by which more economic operation may be brought about. For instance, higher sustained and average speeds, heavier car and train loads, lower maintenance costs, and a strong competitive position with other transportation agencies can be brought about by investment in or expenditures for necessary additional facilities or improved operating conditions.

The trend shown in cost per traffic unit and the various suggestions as to possible control have a deep economic significance to the railroad industry in its struggle to offset competition, retain traffic, meet the increasing demands for better service, make an adequate return on investment, and thus insure continuation as an independent transportation agency.

However, there are other ways to control costs per traffic unit besides the addition of facilities, labor-saving devices, and so on. These methods are through operating controls and more economical operation. Some of the more prominent ways in which this can be done are listed on page 44 of the report.

This subject is to be expanded somewhat and continued, so that the results and the significance of railroad operations during the immediate post-War II period may be included in the report.

Vice-President Schwinn: This committee, in outlining the trend in the cost of transportation, is giving us all plenty of food for thought to analyze our own problems at home.

Chairman Nye: The final report of Committee 16 on Assignment 7: Coordinated highway service and its effect on the economics of railway operation will be presented by Mr. E. G. Allen, chairman of the subcommittee.

E. G. Allen (Atchison, Topeka & Santa Fe): This is a final report submitted as information.

It was not long after this subject had been assigned to the committee by the Board of Direction before two very excellent reports on practically the same subject were completed by two highly qualified outside sources. These two reports are known as the Lake report and the Middleton report.

The Lake report was developed by the Subcommittee on Highway Motor Transport of the AAR under the chairmanship of Mr. H. R. Lake, who is general manager of the Santa Fe Department of Highway Motor Transport. The Middleton report was by Mr. P. Harvey Middleton, who is now president of the Railway Business Association of Chicago.

Excerpts from the Lake report were printed last year, as last year's report of the committee, Proceedings, Vol. 48, 1947, page 167. Excerpts from the Middleton report appear as this year's final report of the committee on page 45.

It might be well to state that both the Lake report and the Middleton report were given wide distribution, having been sent to executives of practically all the Class I railroads. However, in case additional copies are desired by anyone, the question of whether they are available should be taken up with the Washington office of the AAR for the Lake report, and with the Railway Business Association, First National Bank Building, Chicago 3, for the Middleton report.

Chairman Nye: That concludes the presentation for Committee 16.

Vice-President Schwinn: Once more Committee 16 has not failed us. It has given us a very, very interesting report.

Mr. Nye, I understand that this appearance with your committee terminates your services as the chairman. The Association is indebted to you for the manner in which you have carried out your tour of duty as the leader of this important committee.

If there is no further discussion, the committee is now excused. (Applause)

Discussion on Highways

(For Report, see pp. 88–94.)

(President Chinn presiding)

Chairman W. J. Hedley (Wabash): The report of Committee 9 consists of some recommendations for changes in our Manual material. This report has been prepared with the assistance of Subcommittee 2 on Design and specifications for highway crossings at grade over railway tracks, under the chairmanship of Mr. R. E. Warden, engineer public improvements, Missouri Pacific Railroad, and, of course, with the Subcommittee on Revision of Manual acting under the chairmanship of Mr. H. G. Morgan, signal engineer, Illinois Central System, but was actually developed by the committee acting as a committee of the whole in meeting held in September.

I will outline to you the recommendations we are making. If at any time, in the progress of my remarks, you have questions to ask or suggestions to make, I will appreciate it if you will just make it known because it is my intention to proceed through the whole of the report and then ask for adoption on the part of the Association.

The first recommendation we make is for the deletion of two sections of the Manual appearing under two headings: One, the Specifications for Highway Grade Crossings and Approaches Other than Those for Which Requirements Are Stipulated by Law, and the other, Specifications for Preparation of Track Structure, with the Crossing and Approaches for Construction of Street Crossings over Railroad Tracks. There is a certain amount of duplication in those two sections of the Manual.

We are recommending the deletion of those, and the substitution of general specifications for highway grade crossings over railroad tracks, which you will find printed in the bulletin.

My attention has been directed on the part of one member of the Association to the fact that an addition to what we have printed in here would be in order. Section 2 of this item, beginning on page 89, extending on page 90, sets out the general requirements for crossing approaches and is a general specification for grading crossing approaches. It has been called to our attention that this specification would not be suitable in the event of a crossing on a curve where there was an appreciable amount of superelevation. I am going to suggest the addition of these words in the first line at the top of page 90, followed the word "thereof," "and where superelevation would not dictate otherwise."

The effect of that would be to allow modification of the standard vertical curve and standard approach grade on crossings where there is a large amount of superelevation.

At the bottom of page 90 we set forth a number of types of grade crossings for which we will have specifications in the Manual, at the end of the report this year, assuming that our report is acted upon favorably.

We will have a specification for bituminous crossings, a redraft of which is contained in this report; a specification for wood plank crossings, a redraft of which is contained in this report; a specification for prefabricated sectional treated timber crossings, which was adopted in 1946; a specification for precast concrete slab crossings, which was adopted in 1937; a specification for monolithic concrete crossings, which was adopted in 1940.

The effect of the change we are making in the Manual is that, with this general specification, which is the number one item we are recommending this year, and the

specifications for the particular types of surfacing materials, you will have in the Manual a complete specification for the preparation of the track structure, the approaches to the crossing, and the construction of the crossing itself.

The second item of our recommendations consists of the revision of Specifications for the Construction of Bituminous Crossings.

The third consists of the deletion from the Manual of the Specifications for the Construction of Rail Type Street Crossings. It is the feeling of the committee that this crossing is not generally suitable. It may have certain special applications that are satisfactory, but there are a number of basic objections to it. It makes a crossing which is rather difficult to remove and put back in track maintenance, and it imposes some inherent difficulties, if you are trying to use it in signal territory.

For those, and some other reasons, we recommend the removal of it and no substitution in its place.

Item No. 4 of our recommendations consists of the deletion of the existing material and the substitution of a new specification for the construction of wood plank crossings.

Item No. 5 recommends the deletion of the material bearing the heading, Proper Vertical Curves on Highways for Grade Separation Projects. It was our conclusion that the specifications for vertical curves on highways is not a proper function of the American Railway Engineering Association and can better be handled and standardized by other organizations such as the American Association of State Highway Officials.

In item No. 6, we recommend the deletion of the material appearing under the heading:

Principles for Determining the Relative Benefits to the Public and Railroads from:

Grade Crossing Protection
Elimination of Grade Crossings
Reduction of Traffic on Highway Grade Crossings.

Those are rather important items. The material in the Manual now is out of date. We believe it ought to be removed. We have a subject for study next year that we hope will develop some up-to-date material to put in place of this.

Item No. 7 consists of the removal of the present material and the substitution of the following, under the title: The Use of Center Columns for Highway Grade Separations. I quote the entire item:

"Center columns shall be used only when opposing traffic lanes are or can be separated by a median strip extending to the top of the highway approaches or to the next street intersection beyond the top of the highway approach."

Item No. 8 consists of a minor change on page 9–17 of the Manual under the heading: Highway Crossing Signs and Signals. We recommend the deletion of two words, the effect of which is to require that the operating circuits will operate signals until the rear of the train clears the crossing, whereas heretofore there has been a permissive arrangement that they may operate only until the rear of the train reaches or clears the crossing. Modern practice requires that they operate until the train clears the crossing.

The last item in our recommendations consists of the substitution of new drawings for 18 of the drawings now contained in the Manual for crossings signals, the details of which are prepared by the Signal Section, AAR, and all the revisions that have been made in the new drawings are rather minor in nature, the technical type. They do not affect the general functioning of the signals, but it is our thought that our Manual should be brought into conformity with the most recently adopted revisions of the Signal Section.

Mr. President, I move the adoption of this report and the changes in the Manual recommended by it.

(The motion was seconded, put to a vote and carried.)

Chairman Hedley: That concludes our report.

President Chinn: Mr. Hedley, you and your committee are to be congratulated on presenting a very valuable report and are now dismissed with the thanks of the Association. (Applause)

Discussion on Buildings

(For Report, see pp. 119–122)

(President Chinn presiding)

Chairman H. C. Lorenz (Cleveland, Cincinnati, Chicago & St. Louis): This committee was assigned eight subjects for consideration through the year 1947. We are reporting only on one subject at this time, namely Subject 2—Specifications.

We have prepared and submit for your criticism: First, specifications for timber connectors in railway buildings, and, second, specifications covering installation of copper tubing, both of which will be presented by Mr. Flechter, chairman of the subcommittee.

R. L. Fletcher (Timber Engineering Company): Due to the more or less wide acceptance of many new materials in buildings and their use, the committee thought it would be well to prepare some preliminary specifications for their use. Of these, we have prepared two, one of which embraces the Specifications for Timber Connectors in Railway Buildings, which have had increased use since the war.

In the report, in the third paragraph, I would like to make a change. The ASTM Designation A 17 has been discontinued since the preparation of our report, and that designation is now A 273.

Other than that, there are no changes in either this report or the Specifications for Copper Tubing.

President Chinn: Do I understand this is being offered this year for information and will be offered next year for adoption in the Manual?

Chairman Lorenz: That is correct.

President Chinn: Thank you, Mr. Lorenz. Before dismissing your committee from the platform, I want to congratulate you on your faithful service as the chairman for the last three years. The term you are now completing embraced a portion of the war period and was by no means an easy one for the conduct of committee work. We thank you and your committee.

The committee is now dismissed. (Applause)

Discussion on Cooperative Relations with Universities

(For Report, see pp. 285–305.)

(President Chinn presiding)

President Chinn: The chairman of this committee is Mr. F. R. Layng but, unfortunately, due to illness in his family, Mr. Layng cannot be here. For this reason the report of the committee will be presented by the vice-chairman, Mr. S. R. Hursh, assistant chief engineer—maintenance of the Pennsylvania Railroad. With the termination of this annual meeting, he succeeds Mr. Layng as chairman of the committee.

Vice-Chairman S. R. Hursh (Pennsylvania): Again I am substituting for Mr. Layng, as President Chinn told you. It is regrettable that he cannot be here, being past president and having been a very worthy chairman of this, what I consider, very important committee.

You gentlemen listened this morning to Mr. Chinn's address emphasizing the importance of this Association to this country, what it means not only to all of our railroads but to the railroads of other countries. You listened to Mr. Aydelott as to what the organization is doing. To my mind, that emphasizes the importance of Committee 24. If we are going to continue with what Mr. Chinn emphasized this morning is our duty, if we are going to carry on research—what Mr. Aydelott emphasized to you—it is very important that Committee 24 function.

A lot of you are members of the committees on Track, Roadway and Ballast, and many of the other 21 important committees, but I think the importance of Committee 24 is such that it needs the help of everyone, because, unless Committee 24 functions, we are not going to get new blood into the railroad organizations of this country. That is the prime importance of this committee, to sell the railroad industry to the graduate engineers of our American colleges and universities, to sell the industry as an industry and to sell your particular railroad to those boys, that we may get new blood, a certain percentage each year, if we are going to have outstanding young men in this organization 15 or 20 years from now to carry on the work of the railroads.

Assignment 1 under the chairmanship of Mr. C. H. Mottier, vice-president and chief engineer of the Illinois Central, was for the purpose of stimulating greater appreciation on the part of railway management of

(a) the importance of bringing into the service selected graduates of colleges and universities, and
(b) the necessity for providing adequate means of recruiting such graduates and of retaining them in the service by establishing suitable programs for training and advancement.

Mr. Mottier!

C. H. Mottier (Illinois Central): We are presenting this year our second report on this subject. Last year we emphasized the need for employment of carefully selected engineering graduates and the procedure followed in recruiting them.

It was emphasized that it was necessary to pay as high a salary for our employees as is generally paid in industry, and to collect some information on the salaries now being paid and also employment procedure, we prepared and sent out two questionnaires: One to the railroads and one to the colleges.

The questionnaire that was sent to the railroads was answered by 33 carriers, representing more than two-thirds of the mileage of Class I railroads.

I cannot take the time to review the information in detail but if you will refer to Table 1 which presents this basic information on salaries, you will note that we have set down there the minimum average and maximum starting salaries paid in 1946 and also in the first seven months of 1947.

If you have the bulletin, I would suggest you look at that table, and I will attempt to point out a few of the pertinent points. On the roads reporting, you notice at the bottom of the table there were 130 engineering graduates employed in 1946, of whom only 88 were still in service on August 1, 1947; in other words, in an average length of employment of about one year, one-third of the new graduate employees had left the service.

This calls attention to a rather serious problem faced by the railroads in recruiting engineering graduates. I did not imagine that the turnover would be as great as that.

In the entire 12 months of 1946 there were 130 graduates employed, whereas in the first seven months of 1947 there were 159, which shows a favorable trend. The average salary of the 1946 graduates was $247 per month, and in 1947 it was $255 per month. It is very important, in this connection, to remember that the cut-off date for receiving this information was September 1, 1947, so that none of the salary data reported has been influenced by the 15½ cents per hour pay increase granted nonoperating employees which was effective on September 1, 1947.

Other pertinent information obtained from the carriers is summarized in Tables 2 and 3 on page 289 and in Table 4 on page 290. I cannot take the time to review them.

On pages 290 and 291 we have quoted replies from six railroads which give a fairly good cross section of all the replies received. I think you will find them interesting, and they will probably reflect the experience you have had on your own railroad. They bring up quite a number of points that we discussed in last year's report.

The chief engineer of railroad No. 11, at the bottom of page 291, calls attention to the fact that the organization of technical men on his railroad has had an adverse effect on their employment of graduate engineers.

In last year's report reference was made to a study of engineering salaries, made by the Engineers' Council of Professional Development, which gave the average salary paid an experienced graduate engineer as of May 1, 1946 as $206 per month. That investigation covered all types of engineers. As we are particularly interested in civil engineering graduates, our questionnaire this year was limited to civil engineers.

In Table 5 on page 292 you will note that it gives the minimum average and maximum starting salaries paid 955 graduates from the 53 colleges in the first seven months of 1947.

I think we should say here, for the benefit of these colleges, that we secured a list of every technical college we could locate in the United States, and I think we have got them all, and every college replied. That is remarkable.

The information was presented so that it could be used in the case of 53 replies, which is a remarkable coverage. Unfortunately, these same colleges reported on only 53 graduates employed by the railroads, which was only about 5.5 percent of those reported on, and therefore is not a sufficient coverage to draw any conclusion so far as the salaries paid graduates employed by the railroads is concerned.

It is rather interesting to note, however, that the average salary of all of the civil engineering graduates was $253 which compares with $255 reported by the railroads, almost exactly the same.

Then in the previous table the colleges reported an average of $256 for those employed by the railroads. So those three checks are almost identical. Of course, that is obviously a coincidence. It does, however, support the contention that the railroads are presently paying rates comparable to those paid by industries, and that is the main point we were trying to ascertain.

On pages 293 and 294 are reported replies from six colleges which gave a fairly good cross section of all of the college replies.

The views expressed by College No. 5 at the bottom of page 293 and the top of 294 is rather encouraging. I would like to read two or three pertinent sentences from this reply. I will read them from page 294.

(He read the first sentence of paragraph 2, the last sentence of paragraph 4, and all of paragraph 5, which is as follows:)

"I continually urge our boys to give consideration to railway employment, emphasizing the advantages of a career in railroad work and the present possibilities for rapid advancement due to the wide gap in age ranges brought about by the limited employment of civil engineers during the depression and during the war period."

I wanted to read that last sentence because to me it is quite significant. It is a situation with which we are all familiar, and it is one of the keynotes that we have been harping on in this committee for some time. I feel satisfied, myself, not from casual study but a rather careful one, that the lack of interest that was displayed in most of our engineering schools about railroad employment has gradually given way to considerable interest on the part of colleges, and the result, I think, is very encouraging and beneficial.

As a general proposition, I think that we have made remarkable progress in the past two years. Apparently the rates now being paid by railroads generally compare very favorably with the rates that are being paid in industry. Our investigation brings that out very definitely.

I would caution you, however, about drawing erroneous conclusions from the data presented in this report. In the first place, we should keep in mind that these figures, as I stated before, do not reflect a situation which existed after the 15.5-cent-per-hour raise went into effect. That makes a difference of about $32 per month. If you add $32 to these rates which were the average paid for September 1, 1947, you get quite a little different picture. Your $255 goes to $287.

I think you will reach the conclusion that the rates which you will have to pay will range between, maybe, a low of $260, but I would guess a low of about $275, up to $300. Those are rates that might seem fictitious to most of you fellows until you start to figure out what you pay for a plasterer or brick mason or even a paper hanger. Then they do not look quite so big.

There is another item that you should keep in mind when you compare the rates paid by railroads with most industries, and this is a point we have not developed in our report. If you take $275 as the base and our 5.75 percent deduction for railroad retirement, that amounts to $15.81, as compared to $2.75 for a 1-percent social security deduction. So, on this basis, the $275 railroad employee gets about $13 less take-home pay than does an employee at the same rate working for industry.

Vice-Chairman Hursh: The next report, Assignment 2, will be presented by Professor Sadler in the absence of Dean Davis of the University of West Virginia who, because of college duties, is not able to be present.

Its purpose is to stimulate among college and university students a greater interest in the science of transportation and its importance in the national economic structure, by cooperating with and contributing to the activities of student organizations in colleges and universities.

I would like to say, before Professor Sadler comes up here, to all of you members representing the railroad industry, this committee cannot do this job alone. There are, roughly, 140 colleges and universities that have an accredited course in engineering. I would say the railroad industry as a whole gets men from possibly 75 of them.

During the past year Dean Davis solicited members of the railroad family to make talks to the student chapters of ASCE at the various colleges and before classes of the various engineering courses, and he had splendid cooperation. That committee will continue that work during 1948. It will be necessary that we have the wholehearted support of all of you railroad people. Let me say that it is not necessary that a man be a chief engineer or a high ranking officer of your particular railroad.

I have found that, in making these contacts with the colleges, if you can pick out some young man who has had a fairly good success in his short life on the railroad, he has a greater appeal in talking to these young boys in college. There are many of you people, I am sure, who did not know what you were going to make your life profession when you started to school. Possibly it would have helped you if, in your freshman year or sophomore year, you had some railroader come along at that time, inasmuch as you are now railroaders, and talk to you and tell you the good points as well as the bad, and encourage you, so that while you were going through your college course, you would have had some object in view as to what you are going to do. So that the young man is of just as much help as a chief engineer. The chief engineer, in most cases, is so busy that it is pretty hard for him to go around to some college and make a talk.

During the ensuing year, if your railroad gets a request, or if you are located near some college town, I am hopeful you will volunteer and offer your services to Dean Davis to carry on this very important work of selling the railroad industry to the boy going to school.

Professor Sadler!

W. C. Sadler (University of Michigan): The objective of Assignment 2 is to develop collegiate interest in transportation. Possibly the term "transportation" is too broad. At least it is difficult to visualize a society of railroad men trying to arouse the interest of college faculties and students in the competing agencies of air, pipe lines, waterways and highway transport.

At any rate, the present interest of the American Railway Engineering Association is directed to the definite dearth of superior railroad applicants from engineering colleges. That is the problem. The factors governing employment are as follows:

First, the stability of the industry is of great importance, and present-day seniors are still conscious of the unemployment of depression years. A large corporation can ride out some pretty lean years.

Second, the probable duties of employment are important. Students frequently say that they cannot endure an entire lifetime at a drafting board. In this regard, I am sure that nearly every railroader in this room can recall his own personal experience on track, yards, terminals, bridges, buildings, river and harbor work. The life of railroading is diversified and fascinating, if nothing else.

Third, during the past two decades there has been developed two broad types of employment for engineers. In one group is the governmental work supported by taxes and organized upon a civil service basis, where the promotions and wage increases are measured by the years of service. In the other group is private industry, where advancement is measured by the capacity to produce. This latter rough-and-tumble type of commercial competition will appeal to the vigorous, robust and self-confident students, if the story is properly presented to them. This point is particularly attractive in railroad work.

Fourth, the student may well inquire what is at the top. "Just how green are the pastures, if I have the stuff on the ball and should get the breaks?" The reply might indicate that a railroad president gets $75,000 or $140,000 per year. But it is more impressive to indicate that there are 30 to 210 positions paid over $10,000, depending on whether the company is a medium sized railroad or one of the largest. But of even greater significance is the present need for promising young men who have the potential capacity to step forward into positions of very great responsibilities.

With these general factors in mind, the interest of this subcommittee was directed to assist in arranging a speaking program before college societies, by representatives

of various railroads, both large lines and small. The details of this speaking program are presented in the accompanying report.

Although the actual results of this type of a program are somewhat intangible, and they are difficult to measure, yet it is probable that the fine speeches were very effective in presenting the interesting and profitable phases of railroad work. (Applause)

President Chinn: Thank you, Professor.

E. M. Hastings (Richmond, Fredericksburg & Potomac): I am not going to discuss this phase of the report but I feel the urge to add just a little something to what Mr. Hursh has said to you about your responsibility toward these young men who are completing their engineering courses. Possibly I can bring it to you more forcefully by giving you personal experiences.

All of you men know the great interest that I have had in the young man who is completing his engineering course and is coming out from our engineering institutions, for some years past, and the activities that I have carried on during those years.

Seldom has there come to anyone, I believe, any more or any greater opportunities than have come to me, particularly during the year of 1947, and I find that it is lapping over now into the year that we are in.

I had the rare privilege of speaking to great crowds of students throughout this country, in many of our larger institutions.* At all of these meetings that I have attended, in the question period that has followed the talk that I have given to these students, there have been questions concerning the railroad, because they have all known that I was a railroad officer. The young men are anxious, many of them, for railway service.

All too often I have found that our railroad officers are not inclined to put themselves out too much to visit these institutions. Even though the chief engineer, Mr. Hursh, may be very busy, I believe that many of them would find it very profitable indeed to them, certainly of tremendous benefit to the young men, if they would take the time to visit the institution that is near them. Almost every one of you can find an institution that is pretty close to you.

They also want to hear from the younger men. I like that idea of sending out our younger men who are in railroad service to relate some of their experience.

I have said all this to you because I want to impress on you the fact that the field is ripe to the harvest right now, and it is up to us in the railroad industry, those of us who have come along a little way, those of us who are just coming into it and are interested in it, to present it to these young engineering graduates, because, unless we do it, the railroad industry is not going to advance as it should.

Need I say more to you to impress upon you the fact that is *your* job? Don't leave it to your committee. This committee is small as to number. It is your job. Every one of you have some place in your own territory where you may go and speak to these young men, answer their questions frankly and fully. I think that we will recruit, for the railroads, the future officers of years to come. (Applause)

President Chinn: Thank you, Mr. Hastings.

Vice-Chairman Hursh: The next committee report is one, I will say, of equal importance to railroad officers going and talking to students, and that is Assignment 3—The cooperative system of education for railway service.

We have learned from those railroads who have the cooperative system, whereby the student may go to school three months or six months and then work on the railroad

* In his capacity as president of the American Society of Civil Engineers from January 1947 to January 1948.

three months or six months, that, in selecting those boys from the colleges with which you work on the cooperative system, if you pick that boy, the right kind, or the one you want, that you think is going to make good on your railroad, pick him when he is a freshman, you will make a railroader out of him. If you do not, you will find it out in the first six months that he is working. He will either not like to work or you will not like him, and he will not continue. But it is a wonderful field of stimulating interest in the railroad industry by going to the cooperative schools and employing those boys either while they are going to school, or giving them employment in the summertime, even to the extent of employing the instructors.

If you give employment to an instructor in surveying, or some engineering course, you will find that the pay that you give him is just about equal to what that young instructor is making in college. He is getting money; he is learning something, and he goes back and has a different slant on railroading and as to what he is teaching. So that you railroads that have the cooperative system, I am hopeful that you will continue it and enlarge upon it, because it is a splendid field of getting good men for the railroad.

This report will be given by Professor O. W. Eshbach who is dean of Northwestern Technological Institute.

O. W. Eshbach (Northwestern Technological Institute): This is a progress report.

There is nothing more important in the success of the plan of cooperative education than giving to an employee the opportunity to gain a perspective in addition to actually performing useful work of the railroad industry, and for him to bring that back to his fellow classmates with favorable reaction.

Since the beginning of cooperative education at the University of Cincinnati, which is over 40 years ago, this method of engineering education has grown to include approximately 10 percent of the engineering schools and a comparable percentage of the present enrollment.

In past reports of this subcommittee, attention was called to the value of this procedure in the development of technical personnel on the American railroads. Last year, a comprehensive statement of what was meant by cooperative education, its ideals and objectives, was prepared by the committee. It is logical this year to follow this report with a summary of the degree to which railways are now participating in the program. Unfortunately, a current report of this nature would not be significant, because the schools have not yet been able to return to normal prewar operation, as during the war the selective service regulations were such that cooperative procedures were entirely suspended for students eligible for military service. In most schools, however, the program was continued for those who were physically disqualified for service.

A year ago when most of the veterans returned, it was the policy of most institutions, because of the percentage of married veterans, their added maturity, the scarcity of housing facilities and other factors, to give them the opportunity of finishing school as soon as possible.

Thus, during the past year, enrollments in cooperative education were at a very reduced level. Beginning last fall, however, cooperative schools took active measures to return to normal procedure. During the present year, therefore, increasing numbers of engineering students were placed in industry on a cooperative basis, and next year there should be pretty nearly a normal group. It may, perhaps, exceed it. It should be possible, then, in another year to analyze and report on the kind and extent of this participation, also the student's reaction to it, which has been done in the past from time to time.

In reporting on cooperative education, it is pertinent to emphasize that this is but one method of providing concurrent education and experience during the formative

period in the lives of young engineers. For many years, individual railway companies have employed engineering students during summer vacations. This, and also the employment of faculty members during vacation periods, is regarded as being mutually beneficial to the railway industry and education.

One of the most important advantages both of cooperative education and summer employment is the discovery before permanent employment of those interested in the business, thus adding stability to employment procedures.

The shortage of engineers at the present time and the consequent competitive situation are matters of concern to employers and educational institutions. An appraisal of how long this situation will last is complicated by the lack of knowledge of the future needs of federal, state, and municipal agencies, and also the timing of construction of facilities for the many industrial research and development programs planned by industry at the close of the war. They have been considerably delayed.

A preliminary study of American industries and present engineering enrollments, which approximate 232,000 students—about twice the prewar level, most of which, of course, is taken by the superposition of veterans upon normally enrolled students—indicates that the supply of graduates may overtake the demand by the year 1950.

On the other hand, the Manpower Committee of the American Society for Engineering Education, which is studying this problem, is unable to agree as to what the actual situation will be, and it is thought by many that, if a surplus does exist, it will be quickly absorbed and only last for a very short time.

A full report on the enrollments to date and the report of the Manpower Committee will be published early in the Journal of Engineering Education and should be of interest to the members of this Association. (Applause)

President Chinn: Thank you, Dean Eshbach.

Vice-Chairman Hursh: The final report of this committee is Assignment 4—Investigate textbooks and other material available for instruction in railway engineering, and make pertinent recommendations thereon.

I might say, gentlemen, that I think this was one of the most difficult assignments this committee had. Fortunately, we had it under the chairmanship of Professor Babcock, professor of engineering at Massachusetts Institute of Technology. He could not be present today because of other business in connection with his school. I have asked Mr. Hastings, a member of his committee, to present the report. Mr. Hastings.

Mr. Hastings: I am certainly sorry that Professor Babcock could not be here. This is a difficult assignment.

This year's report included a bibliography prepared by the subcommittee to indicate what sources of material are available for instruction in railway engineering. It includes books on railway engineering and maintenance of way and on route surveying and location; handbooks which include railway engineering material; publications of railway organizations; and periodicals.

The subcommittee has found that there is little uniformity in the scope of the courses now offered in railway engineering. In a few colleges the courses include such topics as maintenance of way, signals, yards and terminals, motive power, train resistance and tonnage rating, velocity profiles and economics of line and grade revision. But in many cases the content is limited to location surveys, grades, vertical curves, spirals and earthwork—topics which are usually included in route surveying courses.

A careful study of the material now available, which is included in the bibliography, indicates: (1) No new books have been published for many years which cover the entire field of railway engineering; (2) a new edition of one of the standard books on the

subject has been published recently; (3) several books have been published in recent years which deal with specific branches, particularly maintenance of way and trackwork, but they would not serve as textbooks for courses in the broad field of railway engineering; (4) reference material is available in the Railway Engineering and Maintenance Cyclopedia, AREA Manual, Proceedings of AREA and other organizations; they provide excellent material for instructors of the courses, but the publications are generally not suitable as text material for students; and (5) Railway Age and its associated Railway Engineering & Maintenance and Railway Signaling are excellent sources of reference.

I commend to you, gentlemen, a careful reading of this subcommittee report and hope that in another year the subcommittee may be able to present a report which will be possibly more encouraging and bring us the news that there have been forthcoming publications or books which may be used universally as textbooks in railway engineering.

President Chinn: Thank you, Mr. Hastings.

Vice-Chairman Hursh: I would like to take this opportunity, upon the request of Mr. Layng, gentlemen, to thank all of you members of Committee 24 and especially the subcommittee chairmen for the wonderful support Mr. Layng received during the past year. We will have four new members for the year 1948, and I am hopeful that you will give the new chairman the support you gave to Mr. Layng.

The new members on the committee for the next year are: E. E. Mayo, chief engineer of the Southern Pacific; W. C. Perkins, chief engineer of the Union Pacific; H. S. Loeffler, assistant chief engineer of the Great Northern, and N. W. Kopp, assistant engineer of the Illinois Central.

That is all, Mr. President.

President Chinn: Mr. Hursh, I think we all agree that your committee is dealing with a very important subject. We thank you for presenting the committee's report. I will also ask you to convey to Mr. Layng our sincere appreciation of the work that he has done on this committee during his term as chairman.

Your committee is now excused with the thanks of the Association. (Applause)

Discussion on Yards and Terminals

(For Report, see pp. 95–117.)

(Vice-President Schwinn presiding)

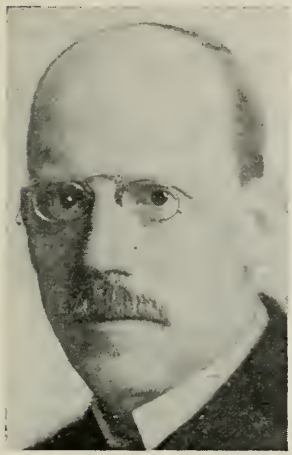
Chairman G. F. Hand (New York, New Haven & Hartford): Before presenting the report of the Yards and Terminals Committee, I want to express to the Association our great loss and regret at the passing of E. E. R. Tratman who was a charter member of the AREA and one of the original 13 members of the Yards and Terminals committee.

He served continuously on our committee from the time he was appointed in 1899 to the time of his death on November 30, 1947, at his home in Wheaton, Ill.

The bibliography which has appeared in our committee's report every year since 1930, including the present report, was prepared by Mr. Tratman. He was a recognized authority in England, and the Railway Gazette of London noted his works and his death, in its issue of January 16, 1948.

Our committee will miss his editorial services and his presence at the convention. A memoir has been prepared for the committee by Mr. Mottier, and I would like to submit it for inclusion in the Proceedings.

Edward Ernest Russell Tratman



Edward Ernest Russell Tratman was born January 1, 1863 in Bristol, England. He was educated in private schools and spent three years, 1881–1884, with Edward Wilson, consulting engineer on railway work, in London, as draftsman and assistant on railway and street railway work. In 1884 he came to the United States and entered the employ of the Long Island Railroad as rodman, which he left in 1885 to become associate editor of Engineering News. He remained with that organization and its successor, the Engineering News–Record, until his retirement July 1, 1932, having been western editor since 1897.

Mr. Tratman was influenced largely into specializing in railroad work by his early training, his experience on the Long Island Railroad, and by editorial work under Arthur M. Wellington when the latter was preparing his book, "The Economic Theory of Railroad Location." With the exception of a small book entitled "Track" written by William Barclay Parsons in 1886, there had been no published work dealing with track maintenance from an engineering point of view. Mr. Tratman filled this need in 1897 when the first edition of his wellknown "Railway Track and Trackwork" was published. Revised editions of this treatise appeared in 1901 and 1908, and in 1926 it was rewritten and published as "Railway Track and Maintenance."

In 1890 and 1894, as special agent of the U. S. Department of Agriculture, Mr. Tratman made detailed reports on metal and wooden railway ties and preservation of wood ties. In 1895 he wrote the railway engineering section of Johnson's Universal Encyclopedia and before his retirement wrote on railway construction and structures for the International Correspondence Schools. In 1888 he was awarded the Norman Medal by the American Society of Civil Engineers for his paper on "English Railway Track." He prepared "Specifications and Standards for Public Works Engineering" in 1933.

Mr. Tratman was a charter member of the American Railway Engineering Association. He had the unique distinction of being one of the original 13 members of the Yards and Terminals Committee, appointed in 1899, and of serving continuously on that committee for 48 years until his death. He was vice-chairman of that committee for eight years, and every year since 1930 he had prepared a bibliography on subjects pertaining to yards and terminals appearing in current periodicals.

Mr. Tratman became a member of the American Society of Civil Enginers in 1886. He was also a member of the American Institute of Mining Engineers, the Western Society of Engineers, the International Tramways and Light Railway Association, the British Permanent Way Institution, American Railway Bridge and Building Association and the Illinois Society of Engineers, of which he was past-president, and for 21 years its secretary.

Mr. Tratman in 1897 married Florence R. Kirkwood, who preceded him in death in 1941. After a two weeks illness, Mr. Tratman died in his home on November 30, 1947, being in his eighty-fifth year. Interment was in Wheaton Cemetery. He was originally a Presbyterian but upon moving to Wheaton, Ill., where he resided for the last 43 years

of his life, he became affiliated with and attended the Methodist Church. He was devoutly religious, studious, meticulous, unassuming, modest and faithful to every trust which he accepted as his responsibility. His fine character and quiet manner endeared him to his associates. Through his extensive writing on technical subjects he has made a substantial contribution to engineering and railroad literature.

Chairman Hand: An important part of the work of the committee this year has been the revision or readoption of those portions of the Manual in which no changes or revisions have been made subsequent to 1936.

The recommended revisions have been studied very carefully and have received the necessary approval of two-thirds of the members of the committee. The recommended revisions will be submitted for adoption and inclusion in the Manual.

A report is also made under Assignment 2—Classification yards, on methods of marking switches. This is submitted as information.

A very important contribution on terminal facilities for diesel-electric locomotives is submitted as information under Assignment 5—Locomotive terminal facilities. It is the intention of the committee to submit this material for adoption and inclusion in the Manual next year.

The Manual now contains up-to-date information on facilities for steam locomotives, and in future years the committee will submit reports on facilities for other and more modern types of locomotives as they come into more general use. For the coming year our work will be confined to facilities for electric locomotives, not that they are more recent than diesels.

Methods for the mechanical handling of l.c.l. freight at freight houses has attracted considerable attention in late years. The methods of handling now in common use, except for some few exceptions, have not changed in many years.—Our report on Assignment 8—Facilities for mechanical handling of l.c.l. freight at freight houses—is, accordingly, of considerable interest. This has to do with handling by conveyor, which method is now in use in this country only by the Railway Express Agency. However, the subject will be continued and include, in future years, other methods for the mechanical handling of l.c.l. freight.

Our first report will be from our Subcommittee 1—Revision of Manual. This will be presented by Mr. Lyford, chairman of the subcommittee.

L. L. Lyford (Illinois Central): This committee report is confined to three of the five general sections into which the Manual is divided. That is it covers terminals, passenger terminals and freight terminals.

Another section is locomotive terminals, which was adopted last year, and there is a section on scales.

This revision takes in the material that is over ten years old, with the exception of Section 34, LCL Freight Facilities. Action on the revision of this section has been deferred for study and will be reported on in another year.

The recommendations of the committee are as follows:

I TERMINALS

Delete sections 11 and 12 under the classification, Terminals, and insert in their place new sections 11 and 12 printed on page 96 and part of 97 of this report.

The last paragraph in 12 should be identified by (e) instead of (a) and the last word in the Manual reference, Form of Agreement for the Organization and Operation of a Joint Passenger Terminal should be "Project."

It is also recommended that we delete the chart entitled, "Typical Outline for Maximum Organization for Terminal Control," which is shown on page 14–3 of the Manual. Reference to this chart is given in the paragraph immediately above, where it says: See AREA Proceedings, Vol. 37, 1946, page 309, for chart showing Typical Terminal Organization. I move the revision outlined under Terminals be adopted by the Association.

(The motion was seconded, put to a vote and carried.)

Mr. Lyford: The second portion of the report is under Passenger Terminals. It is the recommendation of the committee that we readopt all portions as outlined in this report with the exception of the revisions which are also outlined. This is shown on pages 97, 98 and a portion of page 99. The report speaks for itself. I move that the Association adopt this Manual revision material.

(The motion was seconded, put to a vote and carried.)

Mr. Lyford: The third portion of the report is on Freight Terminals. It is the recommendation of the committee that we readopt all paragraphs outlined in this report, with the changes shown on pages 99 and 100.

This includes the readoption of certain charts and tables that are shown in these reports. I move that the Association adopt the recommendations as outlined in this report on Freight Terminals.

(The motion was seconded, put to a vote and carried.)

Mr. Lyford: That completes the report on Manual revision.

Vice-President Schwinn: Thank you, Mr. Lyford.

Chairman Hand: The next report is on Assignment 2—Classification yards. Under this heading the committee has from time to time selected certain specific subjects that we consider should be studied. This is a progress report and is submitted as information and will be presented by Mr. Forman, chairman of the committee on the subject of marking switches.

H. C. Forman (Louisville & Nashville): The information on methods of marking switches was received from 23 different railroads. From the information received, your committee is of the opinion that industry tracks, spur tracks and line of road tracks, which are not a part of a yard, need not be marked, but that there is a definite need for a satisfactory method of marking switches of tracks in receiving, classification, repair and storage yards.

The methods used on the various roads and at different locations on the same road make it practically impossible for your committee to establish a recommendation that will be applicable to all situations. For that reason, we have submitted six methods of marking switches in yards used on various roads.

We may summarize this subject: Many of the roads have found it advantageous to mark switches in yards, using numbers. The number should be clear and easily read, and, where night switching is done, consideration should be given to the use of reflector type numerals. Each road should adopt the method best suited for its purpose. Various methods in use are illustrated in Figs. 1 to 16, incl.

The report is submitted as information only.

Chairman Hand: The next report of the committee is on Assignment 4—Bibliography. This is shown beginning on page 103 and is the last work for the committee by Mr. Tratman. This, together with the bibliography published in previous proceedings, is a valuable index for anyone concerned with yards and terminals. It is something for the record that is available to all who are interested in the design and operation of yards and terminals.

Our next committee report is on assignment 5—Locomotive terminal facilities. This progress report, submitted as information in respect to facilities for handling diesel-electric locomotives, is to be presented by Mr. Hoving, chairman of that subcommittee.

J. E. Hoving (Northern Pacific): Most of the information relative to locomotive terminal facilities has been studied with steam locomotives in mind. However, during the past few years the purchase of locomotives has been predominantly of the diesel-electric type, and the trend is still in that direction.

The facilities required for diesel-electric locomotives are materially different from those required for steam locomotives, and, as the committee has not previously reported on terminal facilities for diesels, our report is confined to locomotive terminal facilities for diesel-electric locomotives.

For the diesel shop building, we have reported on the size of building, construction, tracks, heating, lighting, fire protection, ventilating of exhaust gases, engine pits, jacking pads, drop table, elevated platforms between pits, overhead traveling cranes, machine shop, wheel supply and storage, parts conditioning and cleaning, lubricating oil facilities. In a general way, the report covers fuel oil, sanding, locomotive washing and parts storage facilities as they pertain to diesel-electric locomotives.

Mr. Lacher received a communication from Mr. Hirschthal concerning our report in which he commented as follows:

"Page 11, Heating: Suggest the inclusion of the use of unit heaters.

"Engine Pits: Suggest provision for lighting of the pits; also suggest the inclusion of pits for transfer tables and pits or vats for cleaning motors and armatures and paint spray booths in the main shop."

The committee has studied Mr. Hirschthal's comments and reached the conclusion that the report, in a general way, covers the items raised in his letter.

The report is submitted as information.

Chairman Hand: Our last report is on Assignment 8—Facilities for mechanical handling of l.c.l. freight at freight houses. On my own railroad we have tried to see how we could apply mechanical handling to our needs. Many problems involved in handling l.c.l. freight at our freight houses are nowhere near as simple as the problems confronting the express companies. Express packages are pretty well sized, and can be handled by hand except for very few that cannot be so readily tossed onto a carriage.

Mr. Boessneck will submit this progress report.

W. A. Boessneck (Erie): The assignment was originally proposed for study under the title, "Facilities for conveyor handling of l.c.l. freight at freight houses," and this progress report covers only the conveyors. No installation has been reported where conveyor handling on a large scale has been placed in service in the United States for transfer of l.c.l. freight. It was found, however, that express transfer had been successfully handled by conveyors in recent years in this country.

The report describes a large conveyor type installation used for handling express in the United States and also describes a mechanized freight station located at Birmingham, England. The described installation in the United States is commonly known as the overhead chain conveyor type.

The committee believes it would be difficult to apply and justify the conveyor to the handling of l.c.l. freight for the reasons given in the last portion of this report.

Last year the title of this assignment was changed to its present more comprehensive title, Facilities for mechanical handling of l.c.l. freight at freight houses. This change was made in order that the committee might continue its study and give consideration to handling of l.c.l. freight by mechanical methods other than conveyors.

It is recognized that handling of l.c.l. freight at freight houses is a very costly item to the railroads and has become even more costly in recent years as labor costs have been increasing. There may be many locations where mechanical handling of l.c.l. freight at freight houses could effect a substantial reduction in operating costs.

The committee in its study will include all mechanized equipment such as tractor trailers, power trucks, lift trucks, fork lifts, etc.

The report is submitted as information.

Chairman Hand: This completes the report of Committee 14.

Vice-President Schwinn: We frequently hear the comment that the track has been put up so we can run trains 70 and 80 mph. or more, but when we get our trains to the terminals we can't get them through. Committee 14, gentlemen, has over the years very often pointed the way to get the trains into the terminals.

Mr. Hand, you and your committee deserve the thanks of the Association for the very comprehensive material which you have just presented. (Applause)

Discussion on Water Service and Sanitation

(For Report, see pp. 63–87.)

(Vice-President Schwinn presiding)

Chairman H. F. King (Erie): The report on Assignment 1—Revision of manual—will be presented by the subcommittee chairman, Mr. H. E. Silcox.

H. E. Silcox (Chesapeake & Ohio): Your committee offers the following recommendations with respect to material in Chapter 13 of the Manual.

(He then introduced in turn all of the recommendations for reapproval and minor revisions presented on pages 64 and 65, and his motion for their adoption was duly seconded and carried.)

Chairman King: The report on Assignment 2—Intercrystalline and other types of corrosion of steam boilers—will be presented by the subcommittee chairman, Mr. R. E. Coughlan.

R. E. Coughlan (Chicago & North Western): During the past year your committee has made an investigation of the procedure in the construction of the all-welded locomotive boiler. A number of these boilers have now been put in service on various railroads. For many years the railroads have been endeavoring to obtain permission from the ICC Bureau of Locomotive Inspection to construct and operate welded boilers.

This welding of boilers is particularly important to your subcommittee inasmuch as our studies have developed the fact that intercrystalline corrosion usually starts in seams or rivet holes. The welding of boilers will eliminate seams and rivet holes and the various installations now in service will be followed closely in the continued study of intercrystalline corrosion.

Our report this year is a brief description of the construction of a welded boiler and is offered as information.

Vice-President Schwinn: Thank you, Mr. Coughlan.

Chairman King: Report on Assignment 3—Federal and state regulations pertaining to railway sanitation, collaborating with Joint Committee on Railway Sanitation, AAR—will be presented by the subcommittee chairman, Mr. H. W. Van Hovenberg.

H. W. Van Hovenberg (St. Louis Southwestern): This is a report of progress.

(He read the report on this assignment, which appears on pages 67 and 68.)

Mr. Van Hovenberg: Since the publication of this subcommittee's report, there have been some further activities of the sanitation research project that are worthy of presentation, particularly the present studies on the handling and treatment of toilet wastes from multiple-room cars, involving the use of some type of conveyor for collecting wastes from a number of toilet hoppers and using a single unit for treatment and disposal. Also, in the interest of a better sanitary environment on diners and of facilitating the general operation of dining cars, the Joint Committee submitted to the U. S. Public Health Service on December 22, 1947, the following requests for its consideration: (1) That Section 12.151 of the new Interstate Quarantine Regulations dated June 16, 1947, be revised to permit the installation of garbage grinders on dining cars on the condition that they shall not discharge to the trackways in terminals and coach yards; and (2) that the USPHS collaborate with the Sanitation Research Project in a joint study, at the earliest practicable date, of the use of garbage grinders on dining cars and the disposal of the ground material. The project is continuing tests on new garbage grinders.

Members of the Joint Committe on Railway Sanitation representing the Engineering Division, AAR, are R. C. Bardwell, A. B. Pierce and H. W. Van Hovenberg.

Vice-President Schwinn: Thank you, Mr. Van Hovenberg.

Chairman King: Your committee has no report to make on Assignment 4—Mechanics of foaming and carry-over in locomotive boilers. However,this report will be ready to present next year.

The report on Assignment 5—Current developments in sanitation practices as applied to camp cars and bunk houses—will be presented by the subcommittee chairman, D. C. Teal.

D. C. Teal (Chesapeake & Ohio): This report is presented as information. The basic data for this report were obtained from committee membership in which major United States railroads are well represented.

As to the importance of the subject, it is noted that over 90,000 railway company employees live in camp cars and that 18,000 cars are used for their housing. Under present labor conditions, the necessity of attracting and holding in the service the men so housed is becoming a serious problem. It follows that the provision and maintenance of healthful living quarters is a sound business policy that will pay dividends by

eliminating excessive labor turnover due to discontent and reducing the time losses on account of sickness.

The investigations of your committee indicate that the American railroads are concerned about these matters and that this concern is reflected in efforts to better the lot of their camp car employees. This report describes what is being done along these lines in the field of sanitation.

Under the heading Living Space Requirements it is noted that, in the past the average allotment per man was 30 sq. ft. but that present standards call for around 50 sq. ft. per person.

The section on Heating, Ventilation and Lighting enumerates the improvements that have been accomplished in these aids to healthful living.

The section headed Drinking Water describes past and present methods of procurement and handling, and suggests ways for improvement.

The section on Washing and Bathing compares past with present accepted standards of equipment for this hygienic aid.

The sanitary improvements brought about by modernization of kitchen and dining car equipment are described under the heading Kitchen and Dining Car Facilities.

Under Waste Disposal it is noted that there is considerable room for improvement. The paragraphs on Toilet Facilities mention past practices and discuss merits of the waterless chemical toilets that have been tried in camp cars by several railroads.

Under Insect Control past and present methods are described, and use of the comparatively new insecticide known as DDT is discussed in some detail.

Lastly, the problems of sanitary control are briefly reviewed, with suggestions as to ways of improving. It is pointed out that good sanitation depends on two things, the first being reasonably adequate equipment, and the second, a positive sanitary control program that clearly establishes departmental supervisory responsibilities and instructs all concerned as to fundamental sanitary practices. This report is not complete in that nothing is said about bunk houses, as called for by the assignment. It is therefore suggested that the assignment be continued for at least one more year.

Chairman King: The report on Assignment 6—Silica scale prevention—is a final report and includes all the information now available. It is presented as information, and will be given by the subcommittee chairman, Mr. Ray McBrian.

Ray McBrian (Denver & Rio Grande Western): Silica scale prevention is probably more important than we have realized. Our report covers mostly the present type of power for diesel operation, including that of new methods of silica removal, hydrofluoric acid, and the method of removal of silica by iron shavings.

We decided to continue this subject because of the possibilities and the probabilities of the development of new types of motive power, such as steam turbines, wherein this subject again will be most important. Therefore the subject as found on pages 74 to 77 is offered as information only.

Chairman King: The report on Assignment 7—Requisites of water and wetting agents used in washing passenger train cars—will be presented by the subcommittee chairman, Mr. G. E. Martin. This is a final report and is offered as information.

G. E. Martin (Illinois Central): During the past several years railroad executives have been extremely interested in effecting an improvement in the appearance of the passenger car equipment. The cleaning of the exterior of these cars has been one of the

problems to solve. Many mechanical washers have been installed on various railroads to do this job rapidly.

The report that we now have has reference to the requirements of the wetting agents for doing this job best. A wetting agent is a substance which, when applied to the surface coating, increases the penetrating and spreading action and further has the power to reduce the interfacial and surface tension. Soap is generally a good wetting agent, unless the metal ions in the water are sufficient to destroy its use for that purpose. A number of alkalies, silicates, phosphates and others are sometimes useful and are less costly.

I have with me here two 8-oz. bottles partially filled with Chicago tap water, with not anything added, and in two other bottles I have here a wetting agent known as Santomerse No. 1, which is a powder, and a wetting agent known as NC 9, which is a liquid.

I want to demonstrate to you just what they do when added to water and shaken. I will first use this powder, Santomerse No. 1. (Demonstrating) That was only a small pinch of the powder. Shake it up and it has the same effect as a soap would, even though there is not nearly enough soap in that to do the same job.

(The water in the bottle was converted into "suds.")

The NC 9, which is a liquid and is in the developmental stage, is a wetting agent supposed to be quite powerful. While it is not known for certain, possibly the cost for this would be considerably less than a lot of other things. In order to demonstrate, I can tell you that I have a dropper and will use two drops and no more. (Demonstrating) That does likewise. Both of them are good foamers. It does not take good foaming to be a good wetting agent, but in this particular case both seem to do what is almost like magic, and do appear to be good wetting agents for washing of cars.

Today the principal materials used for washing the exterior of passenger cars are proprietary compounds that consist mainly of a weak acid, with possibly a wetting agent and some type of inhibitor.

One road reports very good results with an oxalic acid solution with a wetting agent, and an inhibitor, used more or less infrequently, possibly once in 30 days, and the remainder of the time the cars are washed with clear water. The constant use of acid solution might result in severe corrosion in certain parts of the cars and cracks that may not be protected. That would remain to be seen.

It is necessary to provide a sufficient amount of water for rinsing the car well. Strong alkali water, such as blow-down water, should not be used.

The type of wetting agent best suited would possibly be governed by the type of soil that is on the cars. It may be that in order to secure the best results for any particular locality, the wetting agent should be selected by trials of the washing of the cars.

Vice-President Schwinn: Thank you, Mr. Martin.

Chairman King: The report on Assignment 8—New developments in water conditioning for diesel locomotive cooling systems and steam generators—will be presented by Mr. M. A. Hanson, chairman of the subcommittee.

M. A. Hanson (Gulf, Mobile & Ohio): The previous recommendations made by your committee for the prevention of scale, corrosion and sludge in diesel cooling systems are still believed to be the best known practice and generally quite satisfactory, namely:

1. Use waters of low TDS, preferably distilled or demineralized water.
2. Use only clear waters with turbidity not exceeding 1.0 gpg.
3. Pretreat the waters to zero hardness.
4. After-treat the water to maintain 1.5 lb. of sodium chromate per 100 gal. with a pH of 8.5 to 9.5.
5. Maintain a hardness in the cooling system at all times below 0.5 gpg.
6. Analysis at least once each week by the railroad's chemists to make certain these standards are maintained.
7. Inspection of the cooling systems at overhaul periods to make certain the desired results are accomplished.

After an extensive search no adequate alternate recommendations can be made. Even if the recommendations of this committee are followed, it is not believed under all conditions the aluminum portions of the cooling system can be completely protected from corrosion.

The locomotive builders are now recognizing this difficulty and are taking appropriate action. One locomotive builder has now eliminated the use of aluminum in contact with the cooling water. Another major locomotive builder has adopted the use of a special corrosion resistant alloy.

Inadequate water treatment is diesel cooling systems, in addition to damaging the cooling system itself, will adversely affect the life of other parts of the locomotive engine by reducing the efficiency of the oil cooling and increasing piston ring temperatures. This results in an increase in oil breakdown, hastens bearing corrosion and tends toward ring sticking.

Since the proper corrective action is known, the attainment of the desired results resolves itself into the utilization of known techniques coupled with adequate administrative control. Its successful accomplishment requires the services of a competent, well trained chemist and the cooperation of the terminal locomotive service forces.

As noted in the previous report of this committee, only the Clarkson type steam generator has been considered in this report. A new type steam generator has been developed and placed in service. Data are being accumulated concerning its water requirements and will be presented in a future report.

In general, two types of trouble have been experienced due to inadequate water conditioning, namely, scale formation and corrosion. Either of these may occur separately or simultaneously, dependent upon the quality of the water used and the conditioning it has been given.

Scale formation can be controlled by a number of methods. The type of treatment to be selected is dependent on the original quality of the water, the number of units in service, the severity of the service and the capital expenditure justified to overcome the trouble experienced.

Scale formation is being controlled by demineralized water, lime soda treated water, zeolite treated water and by internal treatment. The first three of these methods of treatment require a considerable capital expenditure for fixed plant, but under adverse conditions are undoubtedly justified.

Demineralized water, with after-treatment for pH control is undoubtedly the most desirable water supply. It assures scale free operation and sludge free separator return water. It has the further advantage of being the easiest water to passivate chemically for corrosion control.

Lime soda treatment can be used successfully with certain water supplies. It is particularly adapted to waters high in bicarbonate hardness and low in alkali salts. With

this treatment, scale formation in the coils will be adequately controlled, but some sludge will be found in the separator return water which may cause some control difficulties.

Zeolite treatment with after-treatment for pH control is satisfactory for certain water supplies, particularly for water supplies that are initially clear and relatively low in total hardness and alkali salts. With these waters it will produce results comparable with demineralized water except for somewhat less response to chemical passivation for corrosion control.

Internal treatment requires a very small investment, but, to be successful, the chemical used must produce a relatively nonadherent sludge to prevent the various controls, heat exchangers, steam traps, etc., from becoming plugged with sludge. Calcined potassium carbonate is being used quite extensively for this purpose with a good degree of success. Soda ash, phosphate, tannin mixtures have not been too successful, due to the character of the sludge formed. This method of treatment should be limited to waters of moderately low hardness, probably with a top limit of 15 gpg., since with higher hardness waters the amount of sludge formed becomes excessive, requiring very frequent flushing of the water storage tanks in order to keep the various water controls functioning properly.

Tests have shown that corrosion cannot be completely arrested by pH control in the presence of oxygen up to a pH of 12.5. This high a pH value in feedwater is not economically feasible. However, the higher the pH value of the feedwater the slower the rate of corrosion. Tests with deaerated water with a pH of 7.5 or above showed no corrosion. Deaerating equipment is available for installation on the locomotive unit which can give reasonably complete deaeration if the problem of corrosion control is severe enough to require it.

A series of tests was made in an attempt to chemically fix the dissolved oxygen in the feedwater by the use of sodium sulfite. If the feedwater is not hot, the reaction between sodium sulfite and oxygen is very slow, requiring several hours to complete the reaction. The speed of reaction between dissolved oxygen and sodium sulfite is a function of temperature and below a temperature of 185 deg. F. is too slow to be of practical value in restraining corrosion.

Irrespective of the type of treatment selected, the method of control must be accurate and reliable. In addition, analytical control must be exercised frequently enough by a properly trained water chemist to ascertain whether or not proper treatment is maintained at all times.

Chairman King: This completes the report of Committee 13. However, due to my retirement from railroad service and also my retirement from chairmanship of this committee, I would like to express my appreciation to all the committee members for their excellent work and their fine cooperation. I am sure that similar support by the committee will be accorded to my successor, whom I understand will be Mr. Silcox of the C. & O.

Vice-President Schwinn: Mr. King, I think Mr. Martin should be complimented on the presentation of his assignment No. 7. The presentation was very ingenious and, for a moment, I thought he was going to pull a rabbit out of the hat.

Here is an example, gentlemen, of another committee which had a highly specialized job to do for us and which it does well.

In dismissing your committee from the platform, Mr. King, I wish to extend to you all the sincere thanks of the Association. I also wish to thank you personally for your service as chairman, which is now being brought to a conclusion. (Applause)

Discussion on Maintenance of Way Work Equipment

(For Report, see pp. 147–176.)

(President Chinn presiding)

Chairman Edgar Bennett (Southern): Your Committee 27—Maintenance of Way Work Equipment—was assigned 11 subjects last year. Under the first subject—Revision of Manual—we offer some slight modifications to bring some of the matter up to date. We have three progress reports offered as information, five final reports presented as information, and two reports that we were unable to finish this year because of the lack of certain information which we hope to bring in next year.

Of necessity, we depend on illustrations to show the equipment, machines and tools that are described in the reports. Some of our cuts are not as good this year, as they should be.

Our first report is Revision of Manual, and Mr. Westcott, the chairman of that subcommittee, will give the report.

G. R. Westcott (Missouri Pacific): In the Manual, on pages 27–9 and 27–10, under the title Methods of Maintaining Motor Cars, there are now set out certain principles evolved some 20 years ago on that particular phase of maintenance work. At the time that information was placed in the Manual, it was pertinent to the conditions that then existed. It is now realized, however, that it is rather out of date for two reasons, possibly more. One is that the maintenance of motor cars has now been submerged in the more general work of maintaining and using roadway equipment. The other is that maintenance of the machine has become somewhat overshadowed by the care and operation of the machine.

The committee thought well, therefore, to suggest another statement under the title Care and Operation of Maintenance of Way Work Equipment. This statement contained in the report is set up rather briefly and is not intended as a detailed procedure but is, we hope, thought-provoking and will give some suggestion of the things that you need to think about. Privately, I am afraid some of our managements are not thinking about it as much as they should, if we are to use mechanical equipment to its fullest capacity and greatest economy.

In this report there are set forth 10 phases of the care and operation of maintenance of way work equipment. I will just mention these briefly.

(He presented a synopsis of the text matter.)

Mr. Westcott: By a vote of more than two-thirds of its membership, Committee 27 recommends that the statement now in the Manual on Methods of Maintaining Motor Cars be removed from the Manual, and that in its stead there be placed the statement on the Care and Operation of Maintenance of Way Work Equipment as outlined in this report. I move that this action be taken by the Association.

(The motion was seconded, put to a vote and carried.)

President Chinn: Thank you, Mr. Westcott.

Chairman Bennett: The next report is on Assignment 2—Standardization of parts and accessories for railway maintenance motor cars. Mr. Tracy is chairman of this subcommittee and will give the report.

S. E. Tracy (Chicago, Burlington & Quincy): For the benefit of some of you who probably have not had an opportunity to read the report I would like to go over some of the recommendations and opinions of the committee in connection with the three items that are covered by the report.

Pressed steel wheels furnished by manufacturers are either ¼ in. or 5/16 in. in thickness. It is the recommendation of your committee that a regular periodic inspection be made of motor car, trailer and push car wheels with a suitable gage by which the thickness of metal in the wheel tread, throat and flange can be determined.

Wheels should be replaced when wear has reduced the plate thickness in one or more of these areas to ⅛ in. Wheels should be replaced when cracks have developed in one or more of these areas, regardless of the plate thickness of the wheel in the area. Wheels on drive axles should be replaced in pairs of the same circumference.

The second item is windshields and cab tops. It is the opinion of this committee that it is not necessary, desirable or economical to equip every motor car with either a windshield or a cab top regardless of the type of service to which it is assigned. The necessity for and the application of a windshield or a cab top must be governed by the conditions and requirements.

It is the opinion of your committee that it is not necessary, desirable or economical to equip every motor car with an electric lighting system regardless of the type of service to which the car is assigned. Operating conditions, geographical locations and requirements of the service must govern the need for and the application of this accessory.

This report is submitted as information, with the recommendation that the subject be continued.

President Chinn: Thank you, Mr. Tracy. The report will be accepted as information.

Chairman Bennett: We have no report on Assignment 3, but expect to bring in one at the next convention.

Next is Assignment 4—Power ballasting machines—which will be presented by Mr. Rothe, chairman of that subcommittee.

F. H. Rothe (Pennsylvania): This report is submitted as information, with the recommendation that the subject be continued.

The last report on power ballasting machines was printed in the Proceedings, Vol. 45, 1944, page 100. The machine described had certain features which the manufacturer changed in 1946 so as to tamp both sides of each tie at the same time, provide greater tamping power, and a speed averaging 380 ft. of tamped track per hour in stone ballast, for heavy, fast traffic, giving excellent results at reasonable cost.

That part of the report referring to electric vibratory tampers on page 152 should state there are *12* tampers instead of *8* tampers mounted on a suitable frame on a car. This machine is a rather recent development.

While your committee does not have sufficient information on performance, speed, quality of tamping, favorable reports have been received and further facts will be determined for assignment this year.

President Chinn: Thank you. The report will be accepted as information.

Chairman Bennett: Our Assignment 5—Snow removal equipment—will be presented by Mr. Munt, who is chairman of that subcommittee.

A. W. Munt (Canadian Pacific): This final report on snow removal equipment is presented as information.

In compiling the report, your committee has attempted to describe the various types of snow removal equipment available and in use on a number of railroads. Included in the description are machines used many years ago, as well as the modern, more efficient units in use today. We also cover the manner in which they are used and the purpose for which they are mainly employed.

Snow removal is a problem that many railroads have to contend with and involves the annual expenditure of a large amount of money. With this thought in mind, your committee has endeavored to acquaint you with the equipment available for reducing hand labor and the use of which will effect substantial reductions in the cost of snow handling.

President Chinn: Thank you, Mr. Munt. I understand this report is presented as information, and it will be so accepted.

Chairman Bennett: The report on Assignment 6—Power cribbing machines—will be presented by Mr. Keever, chairman of the subcommittee.

A. A. Keever (New York Central): Various types of machines have been developed for cleaning cribs. One type has a scoop or bucket which is drawn through the crib by a winch or other power appliance, collecting material in the crib which is then dumped on the shoulder. Usually, the material in the crib must be loosened with picks or a rooter before the scoop will perform satisfactorily.

An on-track machine has been developed for excavating cribs and depositing material beyond the ends of the ties by a pivoted digger boom equipped with an endless roller chain. The truck frame supports a four-wheel carriage which in turn supports the power unit and the digging and excavating mechanism.

Still another cleaning machine is being built which works on track, takes the ballast out of the crib by pushing the ballast from the end of the tie to a position between the rails by means of hydraulically operated rams, this material then being picked up by a bucket digging conveyor and delivered to a vibrating screen for separation. The ballast is then returned to the crib, and the dirt which has been collected with it is taken by a swing conveyor and delivered to the side of the track or to a small car behind the machine.

Still another on-track crib cleaning machine employs a heavy crosshead extending across the track the full length of the crib. Transversely acting digger bars are mounted on this crosshead. The crosshead is raised by a continuous chain drive and falls freely after being released at the top of the lift.

Three types of these machines are illustrated in this report. This report is presented as information, with the recommendation that the subject be continued.

President Chinn: Mr. Keever, in considering this subject, did the committee give any thought to the type of machine that is sometimes used to clean the ballast out along the tie plates where rail is being laid to reduce damage to cutters when power tie adzers are being used?

Mr. Keever: We felt, Mr. President, dealing with this assignment we would devote our study to the machines which clean the entire crib and not just under one rail.

President Chinn: Is any consideration to be given to these other machines in your further report?

Mr. Keever: This season we expect to have additional machines. This field is comparatively new.

President Chinn: I know it is. Thank you, Mr. Keever. Your report will be accepted as information.

Chairman Bennett: I might add, in connection with the cribbing machines, that we know about the machines to take the ballast away from the surface of the tie, primarily to protect adzing machines, but we did not include them in this report for the reason that the full cribbing operation was under assignment.

There is quite a lot of interest in cribbing operations now, and we believe through this year's work and probably succeeding years we will be able to get a good, sound report that will furnish reliable information to the men who would like to have it.

Our next assignment is 7—Power spike machines. Mr. Etchison, who is subcommittee chairman, will give that report.

F. L. Etchison (Atlantic Coast Line): This report merely describes the power spike machines in general use on the railroads throughout the country, namely, the pneumatic and mechanical. If properly used, they give quality work at economical operation cost, blending in with mechanized forces or other methods of work. Your subcommittee recommends that the subject be discontinued.

President Chinn: I understand the report is presented as information. It will be so accepted. Thank you, Mr. Etchison.

Chairman Bennett: Our next assignment was 8 but, through lack of sufficient information, we were unable to develop a satisfactory report this year. That, again, will have necessary handling. We hope to have a satisfactory report for the next meeting.

The next report is Assignment 9—Flame cleaning equipment for steel bridges and buildings. Mr. Pittman, who is subcommittee chairman, will give that report.

T. M. Pittman (Illinois Central): The report on this assignment is submitted as information, with the recommendation that the subject be discontinued.

President Chinn: It will be accepted as information.

Chairman Bennett: Our next assignment is 10—Machinery and equipment for stabilizing roadbed. Mr. Buss is subcommittee chairman and will give the report.

R. E. Buss (Illinois Central): Your committee did not deem it necessary to go into further discussion on pressure grouting methods, as that had been thoroughly covered in previous reports. Due to the fact there were no improvements in this equipment nor in existing machinery or additional machinery, we decided to discuss other methods of stabilizing roadbed.

We discuss on and off-track machines for driving poles or piling at the ends of the ties, which are illustrated in the report. We submit this as a final report.

President Chinn: The report is submitted as information and will be so accepted. Thank you, Mr. Buss.

Chairman Bennett: Our next report is Assignment 11—Ballast cleaning equipment. Mr. Strachan, who is subcommittee chairman, will give that report.

G. M. Strachan (Atchison, Topeka & Santa Fe): The report, in general, deals with what we have styled eastern and western type shoulder-ballast cleaning machines. The report is submitted as information but I should like to read the conclusion.

(Mr. Strachan then read the conclusion.)

Mr. Strachan: The report is submitted as information and as a final report.

President Chinn: Thank you, Mr. Strachan. It will be accepted as information.

Chairman Bennett: Mr. President, before we relinquish the platform, I would like to state that, through retirement from active railroad service, some of our older members have dropped out, and some of them we expect to have come back with us when they can: G. E. Boyd of the Simmons–Boardman Corporation; C. H. R. Howe of the C. & O.; C. H. Ordas of the Milwaukee; R. M. Leeds of the L. & N.; and Mr. Westcott tells me he soon is going to drop out, possibly some time this year.

The valued judgment and guidance that has been given us by these men who have been with the committee ever since its beginning have been keenly appreciated. We now need more younger equipment men in the committee, and urge the chief engineers to see to it, that they have representation on Committee 27.

I also wish to state there is no use to have a man assigned to the committee unless you encourage him to attend the meetings. Unless we can get real work from our committee members, we cannot hope to bring in the type of work you expect.

I would like also to take this opportunity to thank all the members of the committee for the splendid cooperation and the help they have given this year, and we expect the same cooperation through this coming year.

President Chinn: Mr. Bennett, you and your committee represent a group made up chiefly of specialists in a field of growing importance. You have presented an excellent report, and you receive the thanks of the Association.

I listened to what you had to say about getting some younger men from the equipment field on your committee, and I am sure that the secretary has made a note of that, and the Board will give that attention in the coming year.

Your committee is excused with the thanks of the Association. (Applause)

Discussion on Economics of Railway Labor

(For Report, see pp. 135–144.)

(President Chinn presiding)

Chairman J. S. McBride (Chicago & Eastern Illinois): Committee 22 is reporting on four subjects this year. Two of the reports cover the labor economies of welded rail, one a rail in long stretches, the other a rail in special locations. There is also a report on methods and labor saving equipment to offset increased costs. The fourth report deals with the labor economies by adherence to safety precautions.

The committee records, in a memoir, the loss by death during the past year of Mr. James B. Martin, an active and valuable member of this committee for 12 years.

The first report is on Assignment 2—Analysis of operations of railways that have made marked progress in the reduction of labor required in maintenance of way work. This report will be presented by Mr. W. E. Cornell.

W. E. Cornell (New York, Chicago & St. Louis): This report is a compilation of the record of the actual man-hours of labor required on certain items of track maintenance and covers a period of 8.5 years on four test sections totaling 44 miles of track.

As a prelude to preparing this report, the committee made an inspection trip over approximately 167 miles of the Delaware & Hudson Railroad. During this trip we were afforded the opportunity to get on the ground at several locations to observe the track structure more closely. We found the roadbed and track structure to be in excellent condition of maintenance.

Your committee feels the indicated savings of around 30 percent of track maintenance labor on the continuous welded track is rather impressive, and that the subject is worthy of your careful consideration. Your attention is also directed to the reports on assignment 4 and assignment 6 of Committee 4.

The report is offered as information.

President Chinn: Thank you, Mr. Cornell. It will be so accepted.

Chairman McBride: The report on Assignment 3—New methods and labor saving equipment to offset increased costs—will be submitted by the subcommittee chairman, Mr. C. G. Grove. Mr. Grove!

C. G. Grove (Pennsylvania): This report is submitted as information. New methods and labor saving equipment to offset increased costs comprise an objective that is constantly with us. Unless we solve this problem, we will not certainly make the progress that we should on the railroad and survive.

The subject of the report restricts the analysis to new methods and new equipment. Many worthwhile changes have been made in work equipment, although not many new machines have been produced. This report therefore deals largely with refinement in methods and in the application of improved machinery.

There are many angles from which this subject may be approached, and your committee has thought that the most important ones have to do with improved supervision, careful planning and programming of work, applying material at less cost, and the use of machinery and equipment to offset the increased cost.

The use of machinery described in this report, supplemented by many other up-to-date methods, will bring about a reduction in the cost of maintaining our railroads. We believe, however, that reducing the cost of maintaining our property may be supplemented by improvement in the esprit de corps and morale, a field which holds promising dividends and should not be neglected.

We all know that, in the analysis of many projects that we have before us daily, if we can get the supervision and get the men into the spirit of the work, remarkable results will be achieved.

This report is final and submitted as information.

President Chinn: Thank you, Mr. Grove; it will be so received.

Chairman McBride: The report on Assignment 4—Labor economies derived from continuous welded rail in special locations—will be presented by the chairman of the subcommittee, Mr. J. P. Ensign.

J. P. Ensign (Pittsburgh & Lake Erie): This is a study of labor economies derived from continuous welded rail in special locations and is a final report submitted as information.

In considering this subject, we found very little information is available on actual costs. What little is available indicates that there is a labor economy, at these special locations, and as this report shows, some of the roads have reported considerable savings.

I wish to call your attention to these special locations: (He read items 1 to 7, incl., at the top of page 140.)

Mr. Ensign: I think we should also call attention to the substantial savings reported by two railroads that have submitted reports.

(Mr. Ensign then read the conclusions.)

President Chinn: Thank you, Mr. Ensign. I would like to say that this is a subject that is of interest not only to railroad men but to the public generally, because the Association has received numerous inquiries from the public and from the editors of publications concerning continuous welded rail.

Mr. Ensign: In this connection, I wish to say that I became so interested while preparing this report, that I convinced our management that they should weld up 800 joints this year, which we are proceeding to do.

President Chinn: That is one benefit you get from committee work.

Chairman McBride: That is very true, Mr. President.

The report on Assignment 6—Labor economies to be derived by adherence to safety precautions—will be presented by the subcommittee chairman, Mr. E. J. Brown.

E. J. Brown (Chicago, Burlington & Quincy): The committee would like to call your attention to the importance of the subject. I think we all feel that safety plays an important part in our work, but sometimes we fail to realize or associate it with labor economies. We call your attention to a number of recommendations which have been made in the way of adherence to safety practices and how they affect labor economics. I would like to call your attention to the conclusion on page 144.

(Mr. Brown read the conclusion.)

Mr. Brown: This report is final and is submitted as information.

President Chinn: Thank you, Mr. Brown. I think we can all agree that no job is well done unless it is done safely.

Chairman McBride: That concludes the report of Committee 22.

E. S. Birkenwald (Southern): I wonder if we could have a correction in a statement in Assignment 4. On page 140, in the list of special places where welded rail effects a

saving, in item 4 there is a statement that says, "On bridges and viaducts to eliminate impact."

If that were the case, we would not need to study impact. I am wondering if the committee would prefer to change the word "eliminate" to "reduce."

Chairman McBride: The committee will accept that.

E. M. Hastings (Richmond, Fredericksburg & Potomac): I find myself also a little disturbed because of the fact that three of these reports have been given to us as final reports. I disagree with nothing in the reports. I think the change of the one word now is very proper. But I trust that the Committee on Outline of Work will consider very carefully this matter of permitting these subjects to be written off as final reports. Even though there may be nothing within the next 12 months to report, the subjects are so important and they are so far reaching at this particular time, because of the tremendously high and seemingly increasing prices that we are paying for labor, we should not just brush them off as final reports.

The conclusions are splend'd and up to date, but I think there will also be some conclusions that may be forthcoming within the next 12, 18 or 24 months that also should be brought before the Association.

I ask, therefore, that the Committee on Outline of Work give consideration to that.

President Chinn: Thank you, Mr. Hastings. I think Mr. Lacher has a few comments on that.

Secretary Lacher: In general, with the work of this committee, it has been the policy to take up a subject in any one year and present a complete report of the information available from current developments.

I am sure that neither this committee nor the Committee on Outline of Work has in mind discontinuing these subjects entirely but that they will be reassigned at intervals as new information becomes available.

President Chinn: Does that take care of what you had in mind, Mr. Hastings?

Mr. Hastings: Partially so. The question that sticks in my mind is who knows just when the material becomes available any better than the committee? The Committee on Outline of Work or the board does not know it as well as this committee itself. So, I would rather leave it with the committee as to when to take it up, rather than just wait for a reassignment of it at some future year.

Presiden Chinn: Mr. McBride, do you have something to say?

Chairman McBride: When this committee submits a report as final, it is a good deal as Mr. Lacher has said. It is only final for the time being. The committee is continually reviving old subjects when it feels there is a fruitful field for further endeavor. The committee will continue to do that.

That completes our report, Mr. President.

President Chinn: Mr. McBride, you and your committee are to be congratulated for presenting a very interesting and informative report. You are now excused with the thanks of the Association. (Applause)

Discussion on Ties

(For Report, see pp. 237–242.)

(President Chinn presiding)

Chairman C. D. Turley (Illinois Central): Your committee is prepared to report on four of its eight assignments.

Our first report, Assignment 1—Revision of manual—in the absence of Mr. Duncan the subcommittee chairman, I will present myself.

Your committee recommends the following:

Pages 3–9 and 10—Specifications for Machining Crossties—approved and placed in the Manual 1936. Submitted for reapproval without change.

Page 3–30—Traffic Unit for Use in Comparing Cross Tie Life—placed in the Manual 1930. It is now submitted for reapproval without change.

Best Practice for Tie Renewals, placed in the Manual 1930, is now submitted for reapproval without change.

Pages 3–23 and 24—Specifications for Dating Nails—approved and placed in the Manual 1930, recommended for reapproval without change.

I move the adoption of the reapproval of Manual material.

(The motion was seconded, put to a vote and carried.)

Chairman Turley: Assignment 2—Extent of adherence to specifications—will be presented by Mr. Simpson who is chairman of the subcommittee.

W. D. Simpson (Seaboard Air Line): The object of this assignment is to observe and advise you about the extent of adherence to your specifications for ties. It is an interesting subject of this committee, and we feel that in its report to you there have been included information and advice from which some of us can profit.

This year the committee visited the tie yards at eight treating plants and observed more than 2,500,000 ties. We wish we could tell you that all the lax practices caused by the war conditions have been corrected, but we cannot. However, we do tell you in our current report that the committee was greatly encouraged by the improvements made and by an apparent general effort of all roads to correct their improper practices as rapidly as possible.

The committee is impressed by the increasing extent of mechanization in the handling of ties at the storage yards and with the excellent job of stacking that is being done by that means. This is gratifying for in the more than two decades that this committee has been visiting and objectively observing ties, it has learned, among other things, the importance of correct stacking.

This report is submitted as information.

President Chinn: Thank you, Mr. Simpson. It will be so received.

Chairman Turley: The next report is Assignment 4—Tie renewals and costs per mile of maintained track, as published from year to year from information furnished by the leading railroads of the United States and Canada. This information is now recognized as authority No. 1 on the service life of cross ties on the railroads. The committee is very anxious that this information be correct. If the members will check over the data of their individual railroads and report any discrepancies to Mr. Lacher's office, a correct report is assured. The report is presented as information.

President Chinn: It will be so received, Mr. Turley.

Chairman Turley: Next is Assignment 8—Dimensions of ties. This report will be presented by Mr. Burton, chairman of the subcommittee.

W. J. Burton (Missouri Pacific): Just a few moments ago we heard Mr. Hastings suggest that a committee should not recommend the subject be discontinued. We agree with that very fully, particularly on this assignment.

This assignment this year is a repetition of one which we have had for a number of years and the conclusions are already in the Manual, so I think we are very much in line with what Mr. Hastings has just said.

The report might be said to carry on from where we had to leave off because of the war. About the time the committee's recommendations for longer cross ties were placed in the Manual, the Santa Fe and the Atlantic Coast Line, adopted the 9-ft. length and have used it since.

It seems very probable that had it not been for Pearl Harbor, the action which was initiated at that time would have been carried through by at least a few of the railroads and we think, perhaps by a considerable number of them.

The 8-ft. length or even the 8-ft. 6-in. length have been handed down without much thought for the fact that the proper length of cross tie is a function of the gage of track and it has no relation whatever to commercial lengths of timber, but at least the 8-ft. length apparently originated because that was a commercial length.

The principal argument for a longer tie is the fact that, with the present length, a portion of the support afforded by the tie and ballast is wasted. We all know that we cannot tamp the center portion of the track without the track becoming center bound, so the large investment in the ballast and in the portion of the tie in the center of the track is practically wasted as far as support is concerned.

With the increasing demands for stronger track, it has been shown in our previous reports that greater support can be obtained more cheaply by an increase in length of the tie than by any other process. I think, to clear up the present position, I had better read the present Manual recommendations, which are reprinted in this year's report. The Manual has this to say:

(He read (a), (b) and (c) at the bottom of page 239 and the top of page 240.)

Mr. Burton: Those recommendations were adopted for the Manual in 1942. The war experience and the experience of the two railroads during the period from the adoption of the 9-ft. tie has confirmed one of the important points which the committee had always made in connection with this subject—that the increased cost is not important.

The reason behind that is this: Observations in the field where ties were being manufactured and information secured from tie producers and from the Forest Service have shown that most trees in such areas are cut exclusively for cross ties, and that such trees would make just as many of the longer ties as they do shorter ones.

It has been the practice, not quite so common now, to leave considerable stump when a tree was cut for cross ties. It was sawed off where it was a convenient height for the manual operation of cutting a tree down. But more recently power equipment has come in and made it much less of a backbreaking effort to cut a tree off very close to the ground.

But, as I say, the observations of the committee in the forest and the information secured from those who manufacture ties have shown us that there is no material difference in the number of long ties which can be produced as compared to the short.

Then following through the various operations of producing a tie, hauling it to the railroad, treating it, hauling it out to where it is to be placed in track and placing it in track shows that, of those various operations, the only real cost involved is in connection with treatment where usually one or two less trams can be placed in a cylinder charge. There is, therefore, a justifiable increased cost for the treatment.

The committee also pointed out that, as far as the preservative is concerned, the amount is not in proportion to the increased length because the ends of a stick or timber absorb much more creosote than the center of the tie, and the tie still has only two ends, So, while there is an increase in the amount of preservative, it is not proportionate.

As to the first cost of the tie, there were two confirmations of the fact that the cost is not greatly increased. One of these occurred when the OPA during the war fixed a differential of 10 cents in certain territories for 8-ft. 6-in. ties as compared with 8-ft. ties. In other words, the authorized price was 10 cents more for the 8-ft. 6-in. tie. Thereafter the producers made nothing but 8-ft. 6-in. ties, and it became practically impossible to obtain 8-ft. ties. The only way, practically, that they could be obtained was to buy 8-ft. 6-in. ties and saw off 6 in. In other words, it did not cost the producers 10 cents more to produce the 8-ft. 6-in. ties, and they elected to take the more profitable length, which was the 8-ft. 6-in.

The other fact that I have confirming that is that one of these two railroads, the Atlantic Coast Line, now pays and, I understand has been paying, only 5 cents a tie more to the producer for 9-ft. ties than it pays for 8-ft. 6-in. ties.

In considering the change from a shorter to a longer tie, of course, the comparison should not be made on the first cost of the tie, nor even the cost of the completed tie, but it should be the comparison between the cost of the ties in track. The labor cost of inserting a long tie is no different from the labor cost of a short tie; at least you cannot show any difference. It would require a very sharp lead pencil to figure it out.

So, the committee is merely confirming previous recommendations, and the recommendations which are now in the Manual. We ask that this report be received as information.

President Chinn: Mr. Burton, I was quite interested in what you had to say about being able to get the same number of 9-ft. ties out of a stand of timber as you could 8-ft. ties. I had always understood that it would reduce the number of ties obtained. It is interesting to hear you say that that is not the case. I do not know how many ties normally can be gotten out of the trunk of a tree, but I suppose most tree trunks will run somewhere in the neighborhood of 30 or 35 ft. long. The number of ties you could get, of course, would be the number divided by the length of tie that you are trying to make. You might tell us a little more about that, if you can.

Mr. Burton: What you say would be the first conclusion that I think almost anyone would reach. I don't say there never is a case that you cannot get as many of the 9-ft. as the 8-ft. 6-in. ties, but, considering the actual field practice of cutting down trees and wasting considerable stump, I think the information we have given is correct, and that is supported by the information we have obtained over a number of years both from tie producers and from the Forest Service.

President Chinn: Have you been able to develop any information as to the reduction in maintenance cost per mile of track equipped with 9-ft. ties as compared with track equipped with 8-ft. ties?

Mr. Burton: Some information of that kind is being prepared by two roads where out-of-face work has been done on new cut-off lines. Of course, it is the common practice to put the 9-ft. ties right in the same track along with the shorter ties. Until you have a substantial number of the longer ties in any one section, it is not possible, of course, to draw any conclusion that way.

President Chinn: Thank you, Mr. Burton, for a very interesting report.

Chairman Turley: During the past several years this committee has studied and given rather extensive reports on the cause and control of splitting of ties; also on ways and means for retarding the destruction of ties by mechanical wear. Recently an arrangement has been made between the National Lumber Manufacturers Association and the Association of American Railroads to enter into a joint research project to study these and other closely associated problems. We look forward to some rather outstanding results from this research work, and we hope that, with this information, we will be able to furnish valuable suggestions for extending the life of cross ties.

Mr. President, this completes the report of Committee 3.

President Chinn: Thank you, Mr. Turley. You and your committee are to be congratulated on presenting a very fine report and are now excused with the thanks of the Association. (Applause)

Discussion on Wood Preservation

(For Report, see pp. 177–197.)

(President Chinn presiding)

Chairman C. S. Burt (Illinois Central): This year the report on Committee 17—Wood Preservation is confined to only three subjects. However, if time will allow, we would like to present to you brief oral reports in connection with the study of several other, we think, important committee assignments.

Before proceeding with the presentation of the committee reports, I should like to take this opportunity to record briefly the committee's deep sense of loss occasioned by the death on June 27, 1947, of Ross Hubley, engineer of timber preservation, Great Northern Railway.

Mr. Hubley was a member of this committee for 20 years. During these years he contributed generously toward the progress of our work. Those of us who were privileged to enjoy close association with him are well acquainted with those fine qualities which made his friendship so very pleasant at all times. May the memories we hold of him linger long to lessen the loss we have sustained.

A brief memoir to Mr. Hubley appears on page 178.

Service records have always comprised a very important element in the work of Committee 17. That is true again this year. Test records are covered by Assignment 2, and that report will be presented by Mr. A. J. Loom.

May I say to you, too, that the American Wood–Preservers' Association is enjoying one of its very finest years under the most able leadership of Mr. Loom as its president Mr. Loom!

A. J. Loom (Northern Pacific): I want to call special attention to the splendid records I was able to obtain this year from the Santa Fe. Other than that, the usual service records are printed, and the report speaks for itself. I submit this as information.

President Chinn: Thank you, Mr. Loom. It will be so received.

Chairman Burt: We have no report this year on Assignment 4—Creosote-petroleum solutions—but it is one of our most important studies. Following a rather complete and what seemed at that time to be a final report some two years ago, this committee has been ever on the alert. It has done fine work. To guide that committee in its worthwhile endeavor, we have had the good fortune of having as the chairman a most outstanding man in the wood preserving industry. Mr. R. S. Belcher, manager of treating plants, Santa Fe System.

In the absence of Mr. Belcher, I am going to ask Mr. Walter Buehler, if he won't please say a few words on creosote–petroleum solutions.

Walter Buehler (Lakeland, Fla.): This invitation to report on creosote–petroleum has come on very short notice. Mr. Belcher has been doing a lot of work on the specification for petroleum, specification for mixtures and methods of determining the percentage of petroleum in creosote–petroleum mixtures by analysis. This work is still progressing. So far no results have been obtained in a method to detect the percentage of petroleum in a creosote–petroleum mixture.

Work is also progressing on determining the efficiency of various mixtures from 50–50 down to 25 percent creosote and 75 percent petroleum. Service tests are being carefully examined, but the committee up to date has not had sufficient information from which to draw any conclusions.

President Chinn: Thank you, Mr. Buehler, for your extemporaneous and interesting remarks.

Chairman Burt: Assignment 6 is New impregnants and procedures proposed for increasing the life and serviceability of forest products. We of the committee consider that, too, a most outstanding subject. Again, we are fortunate in having one of the younger members of our organization to guide us in that field. I am sure that he, too, has something in which you will be interested. I am going to call on Mr. Fred W. Gottschalk.

F. W. Gottschalk (American Lumber & Treating Company): Our subcommittee has worked five years. The problem before us is new impregnants, new preservatives. We cannot get an answer overnight, because the only way that you can establish whether a chemical can be used as a preservative is by service tests of 15 years or more.

The present preservatives are excellent, but the question is how are we going to expand? Treated wood is well established in the railroad industry for cross ties and heavy construction, but there are still additional places where wood should be preservatively treated.

In this country we cut 30 billion board feet of wood every year, and of that, only 4 billion are treated. We should be treating about 10 billion. That ties in with the conservation of our forests. We are wasting forest resource by not preservative treating the wood.

During the war we came up to about maximum capacity in what we can produce in coal tar and coal-tar creosote. If we are going to go on into the use of treated wood up into the range above 4 billion, up toward 10 billion, we have to find new preservatives. This expansion is not going to start overnight. This is a long-time program.

Before the war we imported about 30 percent of our creosote. Now we are back up to about 18 percent. During the war we did not import any creosote. However, this work of the committee is now in the field of the toxic salts, chemicals in water solutions

and chemicals in oil solutions, two general types of preservatives that are being reviewed by the committee.

In closing, I might mention that in all our lendlease contributions of cross ties which we started in 1940 and 1941, we gave away cross ties to European countries, untreated. That is just long enough now so that most of those are rotted, and we are going to have to give them another batch because we did not treat the original batch. We cannot waste our forest resources that way by giving our timber away which we need here.

President Chinn: Thank you, Mr. Gottschalk, for your interesting remarks.

Chairman Burt: On Assignment 7—Incising forest products—in the absence of Mr. Walter Arnold, who could not be here because of illness, I would like to refer briefly to the report: We commend it to you as most interesting and worthwhile reading. It points out rather conclusively the advantages of incising heart pine and white oak. You will note from the photographs that there is a very decided and worthwhile difference in the penetration obtained in those timbers that have been incised against those not incised.

We offer that portion of the report as information.

President Chinn: It will be so accepted.

Chairman Burt: Subject 9—Review the specifications for creosote with particular respect to limitation of residue above 355 deg. C., and other revisions resulting from changes in processes of manufacture. I know every member of this Association will agree that there is nothing so vital to performance of wood as a good preservative. Creosote has certainly been outstanding through the years in that respect. To lead us in this study, we have been fortunate through the years in having one of the outstanding chemists and research engineers of our country. Not only has he excelled in his own field but I like to tell him that he now rivals Drew Pearson in his predictions of things to come with respect to the available supply of preservatives. Mr. L. B. Shipley!

L. B. Shipley (Bernuth, Lembcke Company): I am sorry that Drew Pearson isn't here to give us a few words, but you may recall that a year ago I was called upon to express my personal opinion about the creosote situation. It was very fortunate that the estimate that I made through our committee last year proved rather accurate. In other words, during the year 1947 the total creosote produced and the total creosote imported (these are the latest figures from government sources, not from mine or anyone else's) was 195 million gallons for the year. That compares very favorably with prewar figures on production and importation of creosote.

The important thing about that is that it is all right to work on specifications for creosote, but when the time arrives that you haven't any creosote to use, what is the use of working on specifications? But now we do have plenty of creosote, that is, generally speaking. So it is our job to get busy and work again on specifications.

I want to point out that one procedure we are following is to accumulate actual service records on creosote and creosote-like materials in actual service. We are sometimes handicapped by that, even by our best friends because it takes time, money and a lot of trouble to collect actual service records. A service record in which a man says, "I have used so many ties for the last 35 years," without knowing what he used in them and how they were handled, the treating operation and so forth, does not mean a lot, though that 35 years is important. But you have to correlate all of those facts to get them together. So, we are making an intensive survey of service records with a

view of determining whether there is anything in these records to warrant any limitation of the amount of residue above 355 deg. C., which is the feature of our assignment.

I trust that you who have information of that sort will pass it along to our committee because, if we have it, I sincerely believe we will be able to develop results that will be very much worthwhile to our Association.

President Chinn: Thank you, Mr. Shipley. Your report will be accepted as information.

Chairman Burt: Subject 10 deals with specifications for the treatment of wood to make it fire resistant. In the absence of the chairman of the subcommittee, I am going to call on Mr. W. H. Fulweiler.

W. H. Fulweiler (Philadelphia, Pa.): Assignment 10 on fire-retarding treatment is under the chairmanship of Dr. von Schrenk. In his absence, he has asked that I make a very brief report of the activities during the past year. We do not have a formal report but, as a result of an inquiry from the Masonry committee which has an assignment that has to do with fire retarding treatment for timber in tunnel lining, we prepared a recommended specification. If it is passed by our Committee 17 which meets this afternoon, we will forward it to the subcommittee on Assignment 6 of Committee 8. This will be a summary of the information that appears in the Proceedings, Vol. 45, 1944, page 166, and which also includes a summary of the available specifications and chemicals that have been used commercially during the past two years.

The section I am particularly interested in has been seriously delayed for a number of years by waiting for the American Society of Testing Materials, which has a committee on the development of fire tests and laboratory methods for recognizing the efficiency of the treatment, to finish its work on the methods of sampling. You have to get your sample before you can apply the method. The last meeting of the committee was held in Washington about two weeks ago.

I understand, unofficially, that the committee has arrived at a workable method of sampling partially impregnated timber which, of course, is the type of timber that this Association is primarily interested in. When that is officially adopted by ASTM, I think we can promise you that we will then have the tools to work with and be prepared to submit a more extensive report.

President Chinn: Thank you, Mr. Fulweiler.

Chairman Burt: Assignment 11 is—Preliminary conditioning of forest products for treatement by artificial methods of seasoning. Reference is again made to the absence of Mr. Arnold. In his absence, I am going to call on a member of that committee who is thoroughly familiar with the work that is being done. Again you will hear from Mr. Gottschalk.

Mr. Gottschalk: The subcommittee on seasoning cross ties and timbers has been working in the past year on information supplied by the Santa Fe Railway. The problem before us is to prevent the cross tie from checking or splitting. You are all familiar with the C-ironing or S-ironing of the ends of cross ties. That job requires a lot of labor. It is quite time-consuming in the treating plant.

So, the information that we have to report this year is on chemical seasoning. The work there was to use urea, which is a white chemical, a salt that looks very much like ordinary table salt. It is put in about a 10-percent solution in water to impregnate the cross ties in the treating retort at the creosoting plant.

These cross ties are taken out and put in the seasoning stack. The object is to have a shell of about ½ in. of chemical on the outer zone of the cross tie. That prevents the

tie from checking or splitting. It prevents the outer surface from becoming too dry. After the ties are seasoned, then they are taken back and creosoted in the regular fashion that is standard for the industry.

It is estimated that from 10 to 30 percent of the cross ties fail in service or are lost at the seasoning yard because of improper seasoning conditions, and it is believed that the urea is a step in that direction. Of course, it is expensive, and that is a problem to be looked into. The business of using urea is well established on the west coast to prevent Douglas fir timber from splitting or checking under severe drying conditions.

There are a number of other seasoning systems in use today that the committee is investigating and will be able to report in future years.

President Chinn: Thank you, Mr. Gottschalk.

Chairman Burt: In addition to the reports under study, about which you have heard so far this morning, the committee has undertaken a special assignment under the direction of Mr. Martin Jaeger of the Reading Company to bring up to date what we call a preservative survey. That means a record in full detail of the practices among all Class I railroads with respect to the amount of and kind of preservatives used for the treatment of various materials and also the processes. That is almost in final form today. We hope to have it available for its appearance in an early bulletin.

Information gained through that survey seems clearly to point out the elimination of the use of coal tar for cross tie and switch tie treatment, and an increase in the content of petroleum used in creosote–petroleum solutions for the treatment of cross ties and switch ties. This appears to be true also with reference to coal tar in creosote–coal tar mixtures for the treatment of the same material.

The last survey was completed in 1938 and appears in the Proceedings, Vol. 41, 1940, page 517. We know you will be interested in this up-to-date record.

Mr. President, that completes the report of Committee 17, and we offer it as information. May we take this opportunity not only to invite but to urge your suggestions, comments, criticisms in connection with any phase of our work. We thank you, too, for the extra time that you have given us.

President Chinn: Thank you, Mr. Burt, and your committee for the report you have presented. You are now excused with the thanks of the Association. (Applause)

Discussion on Roadway and Ballast

(For Report, see pp. 497–534.)

(Vice-President Mottier presiding)

Chairman W. C. Swartout (Missouri Pacific): Before I start the report, I wish to beg your indulgence to say something for the committee.

In the past year Committee 1 has lost, I may almost say, its most valuable member by death. I refer to Mr. Roden who was a member of the committee when he died, and had been vice-chairman for two years. I may also say, if such an office were possible in our Association, he was an "executive officer" of Committee 1, for its entire membership, serving under Chairmen Botts and Hillman and the speaker.

I know that Mr. Botts, Mr. Hillman and I leaned most heavily upon Mr. Roden, because he had the ability to handle the multitudinous details of committee work. In anything that he was asked to do, there never was the answer, "I am too busy."

With his passing, I am afraid that we are going to be hard put for someone to fill his place. Mr. Botts and Mr. Hillman are present, and I am sure they agree with what I have said.

Our first report is on Assignment 2—Physical properties of earth materials. I think that title would be more descriptive if we simply said soil stabilizers. However it is perhaps a little more striking as it is. The report will be presented by Mr. Legro, chairman of the subcommittee.

H. W. Legro (Boston & Maine): The report embraces descriptions of apparatus being used in comparative tests to determine soil pressures on and within the roadbed during the passage of trains. These tests are part of the experimental work being conducted by Mr. Magee and his staff under an appropriation made by the AAR for research into the performance of roadbed soils. By the use of these pressure cells, soil mechanics theory may be checked in a practical way. Their use will be a long stride toward determination of what needs to be done to particular soils to stabilize them, how effective various methods of stabilization are, and what further economies can be developed in stabilization procedures.

This report is submitted as information.

Vice-President Mottier: Thank you, Mr. Legro.

Chairman Swartout: Subcommittee 3—Natural waterways—has done considerable work during the past year but it is not completed. Therefore, no report is presented this year.

Subcommittee 4—Culverts—has prepared a report on wood box culverts. That report will be presented by Mr. Miller.

G. W. Miller (Canadian Pacific): The subject was assigned to the committee about 1944 when it became apparent that materials for more permanent types of structures might not in the near future be readily available, and if the war had continued much longer, we would have been forced to use substitute materials in place of concrete and steel products.

Our study of the subject revealed that several types of wood culverts were being used but none appeared to warrant permanent standards. Gradually conditions have become normal again and the necessity for wood culverts is not so acute. Your committee therefore condensed its findings into a single plan showing a typical culvert built from local timber available where a new line is under construction. The continued use of timber culverts depends on the availability of such material, the cost of other materials and their economic life, in the locality where installed.

This report is presented as information.

Chairman Swartout: Mr. Ashley, chairman of the subcommittee on drainage is not present. However, the work of that subcommittee during the past year has been the accumulation of additional data on adherence to recommended practice. There is a short note of progress on page 508.

The next subcommittee to report deals with Assignment 6—Railway protection. The duties of that subcommittee also include stabilization of track and one other subject. The report will be presented by Mr. Crosland.

B. H. Crosland (St. Louis–San Francisco): Subcommittee 6 has had three assignments falling under the general caption of roadbed protection. Assignment 6 (a) covers the stabilization of roadbed by grouting; (b) construction and protection of roadbed across reservoir areas; and (c) chemical eradication of grass and weeds.

The reports on the first two of these assignments appear on pages 508 and 530. However, there are some general remarks I should like to make about each of them and I ask your help in progressing them further.

Assignment (a) is a third progress report drawn up by the Engineering Division research staff of the AAR under the general direction of Mr. Magee and the direct supervision of Mr. Rockwell Smith who will talk to you later.

As you know, two earlier progress reports have been prepared by the research staff, and they have dealt exclusively with roadbed grouting.

Your subcommittee felt that roadbed stabilization was so important that we should expand the studies to include other methods of roadbed stabilization as well as grouting. To that end, Mr. Smith in his report this year, included a brief discussion of two other methods: one of them dealing with driving of poles and ties, a method most of us have used for a good many years, and another dealing with the method of impregnating the subsoil with sand, on what I would call a mechanical basis, by the driving of piles and filling the holes with sand after the spuds were withdrawn.

Your subcommittee does not feel that these methods are necessarily competitive or conflicting. We do feel that each may be used more economically than one of the others in given locations. It was our purpose to try to present to you sufficient basic information about the different methods so that, in your judgment, you could determine which method to apply to take care of your individual problems.

It is fully appreciated that though all these years of railroading all of you maintenance officers have had a great deal of trouble with unstable embankments, and that you have devised ways and means of correcting this condition. Your subcommittee asks your help. If you have devised any methods that have not yet been reported on, it will be very much appreciated if you would write to the chairman of this committee so that we may have those methods investigated.

Our next assignment is: Construction and protection of roadbed across reservoir areas; specifications. In our report we have tried to present, as published on page 530, a general factual statement covering the conditions surrounding the construction of embankments at reservoir areas. During 1948 we will attempt to develop the formation and protection of the roadbed specifically, which we understand is really our assignment, and we will not deal any more with the general scope of the work.

In formulating the information for specifications, we are going to try to take into consideration soil and climatic conditions, because our studies so far have indicated definitely that the question of slopes is very much tied up with the soils used and climatic conditions.

Our third subject is: Chemical eradication of grass and weeds. We have no report on that subject. However, a good deal of factual information has been accumulated, and we hope in the next report to be able to give you some useful information based on past experience. From that point we hope to go on to develop information on chemicals and methods that will be economically feasible for the eradication of grass and weeds.

The report is offered as information.

Vice-President Mottier: Thank you, Mr. Crosland.

I am wondering if someone wishes to make some remarks on this general subject as discussed by Mr. Crosland.

Mr. Crosland: I might add that the question of construction and protection of roadbed across reservoir areas is very vital to some of our railroads now because of the increased activity on the part of the government in the construction of dams and reservoirs.

There are some questions that appear to be vital in connection with the negotiations that each of you have to carry out with the government engineers. There has been

a good deal of discussion as to whether extraordinary maintenance should be included in attempting to set up funds for capitalization of the cost to the railroad as a result of relocation of lines. However, that hardly seems the function of this committee.

There are other questions that deal with contracts. So, the subject as a whole probably covers most of the committees of the AREA. But if there are any questions, or if any of you have information regarding this subject as a result of experience you have had, we would very much welcome your suggestions either here now from the floor or later in writing, if you prefer.

Vice-President Mottier: Thank you, Mr. Crosland.

Chairman Swartout: At the last two conventions we presented at the close of our report a statement of the research work being carried on by the research staff of the Engineering Division, AAR. We are going to do that today. Mr. Smith is going to give his talk.

Rockwell Smith (Association of American Railroads): This is not in the nature of an address. It is more of a supplement to the committee report.

(Mr. Smith read his paper, which appears at the end of this discussion.)

Mr. Smith: Mr. Crosland remarked about the various types of stabilization, and that is the point I want to conclude with. The best results of any type of stabilization are obtained if the field problem is analyzed and an attempt made to hit the source of the trouble.

So far much of that is speculation, and the manner in which the grout does the work is still a matter of speculation, but our investigation has shown in those cases where the problem is analyzed and an attempt made to reach the source of failure, the best results are obtained.

Chairman Swartout: In connection with Mr. Smith's work which is being directed by Mr. Magee—and as chairman of the committee, I have been in very close touch with it practically throughout the entire time.

Mr. Smith will get a lead on trouble on a certain railroad. He does not know what is is. The only way to do is to go and look at it, study it. He may call upon some of you and write to you suggesting an investigation. You are not only benefiting your railroad, you are getting something "for free," but you are doing a job, if you will cooperate with him to the fullest possible extent in solving what is probably one of the most devious problems in railroad maintenance.

There is a very old saying my father used to repeat, "You can't see what is under the ground." That is very, very true of this. But the more we study it, the more we will know about it. I bespeak for the entire Association, the entire railroad industry, that you cooperate in this work to the fullest extent.

Mr. President, that concludes the presentation of Committee 1.

Vice-President Mottier: Does anyone wish to add anything to what has been said?

F. S. Schwinn (Missouri Pacific): I want to draw a little comparison. We have all seen many beautiful buildings and structures. They only remain beautiful because of their foundations. We cannot have good riding track and we cannot get the benefits of our high-speed streamlined equipment without a foundation. I wish to second what the chairman has asked, that the members of this Association cooperate with this committee in its efforts to give us an answer.

Vice-President Mottier: Thank you, Mr. Schwinn.

I think, gentlemen, this is one of the most interesting subjects now being studied by our Association and one that carries, perhaps, as much potential saving to the railroads as any subject we are studying.

All of you know the tremendous importance of roadbed stabilization. I know on our railroad, the Illinois Central, we have been doing a great deal of it, with very good success. I know that various methods are being employed by practically all the railroads in the United States. If this committee can help us to find out what type of stabilization to use to meet a particular situation, they have performed a real service to the Association.

Mr. Swartout, this completes your three years of chairmanship on this committee. You have done a fine service, and we appreciate your enthusiasm for the work and the contribution that your committee has made. We wish to thank you.

The committee is excused with the thanks of the Association.

Stabilization Treatment of Sliding Fills By Pressure Grouting

By Rockwell Smith

Roadway Engineer, Association of American Railroads, Chicago

You have all heard and read considerable discussion of the pressure grouting process by which cement, sand and water are injected into weak or failing subgrades under tracks. In the past three years considerable work has been done on sliding fills of heights up to 70 ft. and this discussion today will be on a number of these which have been observed in the course of our field investigation into the methods used for roadbed stabilization.

On all the projects that will be illustrated by slides, the predominant soils are clays of medium to high plasticity and soils of this type are present in almost all of the roadbed instability now occurring. Increases in density and weight of traffic have undoubtedly increased areas of weak subgrade; a further increase in these factors will result in additional failures; also under sufficient number and weight of load applications the subgrades of lower plasticity clays and silts could be affected. In other words, outside of a few very special conditions, today's traffic is such as to produce, progressively, instability only in those subgrades containing clays of the higher plasticity characteristics.

Even the clays of the most pernicious characteristics would be harmless without the presence of moisture. Water is the root of all evil when in contact with the soils in railroad roadbeds. A railroad embankment is one of the few soil structures that decrease in stability with time and service. Fills that have been stable for 20 years can suddenly fail and the only explanation is a decrease in the shear strength of the constituent soils. This decrease in strength can be produced only by an increase in the moisture content of the soil or decrease in density, very possibly both.

There has been considerable discussion in the past concerning the origin of the water that weakens the fills to the point of failure. The investigation of the past two years has shown quite conclusively that the bulk of this water is that falling on the track. In some cases of sliding fills, this water can be channeled through the ballast and to the fill from a considerable distance. In others the distance is relatively small. However, the evidence is beginning to indicate the possibility of good results from cut-off drainage across the roadway on the upper approach to fills for which the factor of safety is

close to unity under reasonable assumptions of soil strengths. If cut-off trenches are indicated they should not necessarily replace other methods of stabilization required, particularly if the fill in question is already slipping. Once a fill begins to move it can be assumed that the shear strength has been exceeded and under these conditions movement can continue. It is roughly analogous to the action of steel stressed above the elastic limit.

In the course of this investigation, three general types of fill instability have been observed. The first and the most preponderant embraces those fills unstable within themselves and evidenced by slope failures and plastic flow. This movement is usually slow but continuous, and is often accelerated by a period of continuous rainfall, but sudden movement is not unknown especially if the fill contains voids of appreciable size and hydrostatic pressures act as a booster. That some fills can and do contain considerable free water has been evidenced by the flow of water from a number of fills after a slide of serious proportions.

The second type of fill failure is that of the entire fill moving outward on an inclined and lubricated plane, on or below original ground. Underground water can, for this condition, be the determining factor and conventional drainage can often correct the condition if the water is intercepted prior to its reaching the roadway.

The third condition observed has been a failure in the foundation of the fill such as swampy areas where the underlying material consolidates under the weight of the fill or where this material is displaced laterally allowing the fill to subside. Many fills have a combination of the above three general types.

As you know, we have given a great deal of attention during the past two years to pressure grouting; also the methods used in the grouting. In all cases the technique used is that of the railroad doing the work. In all cases, the work has been very successful in stabilization. For the limited length of time the work has been under service, the maintenance costs reported have shown a saving sufficient to amortize the cost of the stabilization usually within four years. These figures do not include any benefits that may be derived from elimination of slow orders or the saving in ballast.

In conclusion let me quote from the AREA Manual on roadway drainage: "Adequate drainage of railroad roadbeds is a matter of major importance to every railroad company, more particularly so in these times of almost universal demand for high speed in transportation. High speed operation of trains depends primarily upon good track. It is axiomatic that excellence of track depends directly upon the stability of the roadbed. It is quite evident that the stability of roadbed depends upon minimizing moisture and that minimum moisture depends upon adequate drainage."

"It may be said, therefore, that a fundamental principal of railroad location, construction and maintenance is to keep the roadbed dry."

Until we are able to offer a more detailed and technical reason for the apparent success of stabilization by pressure grouting we can say provisionally that its effect is to keep the roadbed dry in those vital areas where movements have occurred or may occur because the roadbed is not dry.

Discussion on Rail

(For Report, see pp. 373–495.)

(President Chinn presiding)

Chairman C. B. Bronson (New York Central): Our report is largely a chronicle of important research projects on rail which have been conducted with painstaking care by experts in this field. The scope of this work covers a wide range of physical, chemical, metallurgical and metallographic surveys, and the use of many delicate and intricate instruments as well as those of a practical nature for both laboratory and field measurements. Let me cite an example: When you can work in the dark, so to speak, behind a pair of joint bars and find out the magnitude of the stresses in rail web and bolt holes with exactness and certainty, you have done something.

A tremendous volume of data is acquired in these research projects which must be digested and coordinated, of which the records in our current report are only a small part of the total.

Our allotted time is short and we can give you only the highlights of this highly technical work in brief and concise form and, we hope, in an interesting, enlightening and absorbing manner. And, in addition, there are some reports of an informative and practical nature such as the data on rail failures, and other subjects.

The Association of American Railroads appropriates yearly a considerable sum for rail research work. We are diligently and earnestly plugging away in an effort to get final answers and solutions to these problems, and we are sincere in the belief that much valuable progress has been made.

The American Iron and Steel Institute is a co-contributor of both funds and expert talent and advice on some of these projects. The cooperative spirit has been excellent, as these affairs are handled through a joint contact committee under the able guidance of Mr. L. H. Winkler, chief metallurgical officer of the Bethlehem Steel Company.

For the last three years our report has opened with a note of sadness as we have had the misfortune of losing able, distinguished and outstanding members by death. Two years ago we lost Mr. Kulp, chief engineer of the North Western; last year, Mr. Yager, assistant chief engineer of the Northern Pacific, and this year Mr. Hewes of the Santa Fe, whose death occurred but two weeks ago.

It is our desire to take a few brief moments to place in the record our respects for this man of such sterling character.

Floyd Sinnock Hewes

Floyd Sinnock Hewes, office engineer of the Atchison, Topeka & Santa Fe Railway System, died suddenly at Chicago, Ill., on March 3, 1948.

He was born in Payson, Ill., on January 25, 1884. He was a graduate civil engineer from the University of Illinois in 1906. Upon graduation he entered into the service of the Chicago & North Western Railway in the maintenance department, and in 1907 entered the service of the Santa Fe and was engaged in construction, maintenance and valuation work in Arizona, New Mexico and Texas. In May 1927, he was appointed office engineer in the office of the chief engineer system, which position he held until his death.

He was married at Amarillo, Tex., February 4, 1917, and is survived by his wife, Serena Middagh Hewes, and three daughters, Martha Louise (Mrs. Dawson Gentry) of Springfield, Mo., Ruth (Mrs. W. S. Black) of Chicago, and Mary Ann (Mrs. Fred Primrose) of Plattsburg, Ohio. There are also six grandchildren.

Mr. Hewes became a member of the AREA in 1911 and a life member in 1946. He was assigned to the Special Committee on Stresses in Track from 1938 to 1940, to the Committee on Maintenance of Way Work Equipment from 1931 to 1937, and to the Committee on Rail from 1935 to the date of his death. While on the last named committee, he was chairman of the subcommittee on causes of shelly spots and head checks and gave freely of his time and ability in the study of means of their prevention.

He was also a life member of the American Society of Civil Engineers, effective January 1, 1948, having joined that association in 1913.

The Rail committee has lost a valued member and friend, valued not only because of his untiring and efficient work but for his fine, unselfish character.

We have also recorded the loss of Professor N. J. Alleman of the University of Illinois, whose death last July terminated some 16 years of very capable and efficient work in rail research.

The first official business is the revision of the Manual, which will be presented by Mr. Poore, representing Mr. Nuckols.

S. H. Poore (Chesapeake & Ohio): Your committee submits the following material, which has been in the Manual for ten or more years, for reapproval without change.

Pages 4–7 and 4–8 (Figs. 1 and 2)

90-lb. RA–A and 100-lb. RE Rail Sections, adopted originally in 1915.

I move the reapproval, without change, of these two items.

(The motion was seconded, put to a vote and carried.)

Mr. Poore: With respect to the material on page 4–12 of the Manual entitled Application of Welded Bonds, your committee recommends the deletion of the present material and the substitution of the following:

"The application of pin connected bonds or welded bonds to the outer side of rail head, within the limits of the joint bars for standard bonding and outside of joint bars for special work where not practicable to apply them within the joint bar limits, is good practice."

The change consists merely of the insertion of the words "pin connected bonds," thus broadening the application of material in the Manual.

I move the adoption of this change.

(The motion was seconded, put to a vote and carried.)

Mr. Poore: By letter ballot, returnable 1947, the Association voted a 3½–6–6 rail drilling for six-hole joints and a 3½–6 rail drilling for four-hole joints in 115-lb., 132-lb. and 133-lb. rails. The vote on this was 685 to 46. The ballot and summary of the vote are printed on pages 376 to 378, and I merely call that to your attention.

President Chinn: No action will be required on that because it has already been adopted by the Association.

Mr. Poore: Following a study of spring washer reactive pressure by the Track committee and reported at the 1947 Convention (Proceedings, Vol. 48, 1947, page 635), your committee recommends a change in the reactive spring pressure now appearing in the 1933 Specification for Spring Washers. The change in this table consists of the elimination of the 1¼-in., 1⅜-in. and 1½-in. sizes, and the addition of the 1-1/16-in. size.

The change also increases the reactive spring pressure. The values in the column of "platens released" have been slightly lowered.

I move the adoption of the above described revision to the 1933 Specification for Spring Washers.

(The motion was seconded, put to a vote and carried.)

Mr. Poore: The committee proposes at this time a definition of the term Transverse Defect. This is to cover current practice in the preliminary classification of a detected rail defect. I will read the proposed definition.

Transverse Defect.—For defects found by detector cars, a tentative group classification, applied prior to the breaking of the rails, of all types of rail defects which have transverse components, such as transverse fissures (TF), compound fissures (CF), and detail fractures (DF).

I move the adoption of the above definition.

(The motion was seconded, put to a vote and carried.)

Mr. Poore: There are certain other items which the Rail committee has to offer for inclusion in the Manual, namely, certain revisions in the rail failure form and certain changes in the matter relating to rail batter. These items will be covered by their respective subcommittee chairmen when they present their several reports.

That concludes, for now, the presentation of the revision of Manual material.

President Chinn: Thank you, Mr. Poore.

Chairman Bronson: Rail failures will be presented by Mr. Barnes, engineer of tests.

W. C. Barnes (Association of American Railroads): Rail failure statistics for the year ended December 31, 1946, are presented as information in the report, to which I refer you for details.

I will therefore confine my remarks as follows: Table 2 and Fig. 3 show that, for reporting roads, the 1945 rollings were the first that were exclusively control cooled. Table 5 shows that the failures of all types presented in control cooled rail rolled in 1936 to 1945, incl., totaled only 8.71 for 100 track mile-years, of which only 0.03 were transverse fissures, and those were not due to shatter cracks.

Table 7 shows the ten-year rate of failure of all types in control cooled rail rolled in 1936, with only 16 percent of those of the plain open-hearth rail rolled in the same year.

Practical prevention of transverse fissures by the use of control cooled rail now focuses attention on failures of other types, such as detail fractures from engine burns and shells.

The use of the revised Form 402–C, which will be presented shortly, because of its more complete segregation of types of failure, will enable failure data in the future to show the beneficial effects of the Rail committee's efforts to reduce failures of those types.

We will now take the proposed 1948 revision of Form 402–C: It is now restricted to the recording of failures in control cooled rail; formerly it included rails of all manufacture. It also differs from the present form in a more complete segregation of the various types of failure as follows: Engine burn fractures, which are primarily due to service conditions are no longer listed with compound fissures and detail fractures but are listed separately at the extreme right of the form and are not to be included in the column showing the total of all types.

The other change is a separate listing of horizontal split heads and vertical split heads which formerly were combined.

The restriction to control cooled rail is due to the predominant interest in this type of rail, as evidenced by its exclusive use by reporting roads since 1944.

I move the adoption of the 1948 revision of the committee of Form 402–C.

(The motion was seconded, put to a vote and carried.)

Mr. Barnes: Form 402–L shown on page 382 is a form for the reporting of annual progressive type failures in rail of all ages made by all processes. The proposed 1948 revision calls for separate reporting of engine burn fractures, whereas they were combined with compound fissures and detail fractures in the present revision.

I move the adoption of the 1948 revision of Form 402–L.

(The motion was seconded, put to a vote and carried.)

Mr. Barnes: The 1948 revision of Form 402–C (a) shown on pages 379, 381 and 382, furnishes instructions for the correct reporting of data on Form 402–C, revised 1948, already adopted. It contains only such revisions as are required to adopt the present form for use with the 1948 revision of this form. Those who prepare the reports on Form 402–C are urged to carefully study this revision, particularly paragraph 2, which reads as follows:

(Mr. Barnes then read paragraph 2 of Form 402–C (a).)

Mr. Barnes: This revision also includes an instruction covering the correct reporting of failures on Form 402–L revised 1948.

I moved the adoption of the 1948 revision of Form 402–C (a).

(The motion was seconded, put to a vote and carried.)

President Chinn: Thank you, Mr. Barnes.

Chairman Bronson: Assignment 4—Methods of hardening rail ends and reconditioning them to control rail battering—will be presented by Mr. Winton.

R. P. Winton (Norfolk & Western): There is a need for an instrument to measure profiles of rail ends out beyond the limits of the joint bars for studies of batter and low joints.

The present 10-in. batter gage shown in Fig. 417 on page 4–53 in the Manual is not entirely satisfactory. Your committee has designed a new profile gage which is shown on pages 400 and 401.

We have made one of these instruments and tried it in the field and it seems to be very satisfactory. However, this profile gage is 48 in. long and requires quite a little skill in operating it, and there is need for a very simple gage which can be easily carried and easily used for measuring batter alone in connection with building up rail ends.

Your committee has designed a batter gage shown as Fig. 3 on page 402 for this purpose. It is very desirable, with both of these instruments, to have instructions for operating the instrument and for plotting the data, in order to come to some conclusions. We have written instructions for the use of these two instruments.

I move that the material now appearing in the Manual under the heading of Rail Batter, on pages 4–52 to 4–54, be withdrawn, and that the new material on the measurement of profiles and batter of rail ends together with the illustrations be adopted and published in the Manual.

President Chinn: As I understand, that is the information and instructions beginning on page 399, under the heading Measurement of Profiles and Batter of Rail, and going down to the top of page 404.

Mr. Winton: Yes, sir, that is correct.
(The motion was seconded, put to a vote and carried.)

Mr. Winton: One of the manufacturers of instruments has indicated his willingness to build these instruments according to these drawings. However, he states if he could make them in lots of ten, the price will be considerably lower. Therefore, if there were several railroads that wish to have these instruments and they would get together and place the order at the same time, they could be bought for quite a little less money. That completes the report.

President Chinn: Thank you, Mr. Winton.

Chairman Bronson: Assignment 6—Continuous welded rail—will be presented by Mr. Schram.

I. H. Schram (Erie): Some of the information we have been keeping has been tabulated from year to year, and we were about ready to close out this report. We found that within the last year or year and one-half there has been a considerable increase in interest in welded rail, and there have been a number of new installations. We have been unable to get all the data on those installations, but we will get it in the next few months.

Therefore, it seems of interest to continue this subject and bring it up to date on these new installations, which will no doubt show better results. In the meantime, we have made the usual tabulations, and three summaries are presented herewith. The first one is a summary of failures. The second one is a little more elaborate because it divides the installations and failures and renewals between those installations in tunnels and those in the open and gives a little more data on failures. Then there is the statement of additional failures.

Those statements are presented as information, but I want to say that a good many of the older installations that have been taken out of the track have been removed from consideration and from the summaries.

I want to mention one more point. This subcommittee was about to get together information on the economies to be realized from the use of continuous welded rail, but Committee 22—Economics of Railway Labor, in its Assignments 2 and 4, made such a complete study that we have dropped our consideration of it. The report of Committee 22 is very interesting, and we have called attention to it in our report. That is all I have to offer.

President Chinn: Thank you, Mr. Schram. Your report will be received as information.

Chairman Bronson: Assignment 7—Service tests of various types of joint bars—will be presented by Mr. Ray McBrian.

Ray McBrian (Denver & Rio Grande Western): This is a final report of the service tests of various designs of joint bars for 112 and 131-lb. rail installed on the Santa Fe and the Pennsylvania. This, however, is not intended to be a final report of the work of the subcommittee, as it is proposed to install, in the immediate future, for service tests, the new joint bars as designed for the rail sections that have been adopted for the Manual.

I want to call your attention to the conclusions. Briefly, I ask you to note especially the effect of the end-hardening and the result of the increase in life of the rail and the joint bar obtained by the use of a longer joint bar.

The other subjects that have been commented on in this report include those under rail head wear, controlled bearing bars and angle bars. This report is submitted as information.

President Chinn: Thank you, Mr. McBrian. It will be so received.

Chairman Bronson: Assignment 8—Joint bar wear and failure, and design—is being covered by rolling-load tests of joint bars, and will be presented by Mr. Jensen of the research staff of the University of Illinois.

(R. L. Jensen, University of Illinois, presented a synopsis of the Sixth Progress Report on Rolling-Load Tests of Joint Bars, page 416.)

Chairman Bronson: Assignment 9—Corrugated rail—will be presented by Professor Cramer through the consent of Mr. Jensen.

R. E. Cramer (University of Illinois): This year an attempt was made to produce corrugations in the side tracks of the Illinois Central Railroad at Champaign, Ill. A six-driver locomotive was used pulling a loaded coal car, an empty coal car and a caboose. Attempts were made to spin the locomotive drivers a part of a revolution while moving at slow speeds. This was not accomplished as the drivers spun continuously once they started to spin. With the train stationary, and the brakes set, it was possible to spin the drivers only two or three revolutions, which produced wheel burns considerably deeper than the hard spots found on corrugated rails. It was judged that only ¼ to ½ revolution would be required to produce the depth of hardness ordinarily found in corrugated rails.

Futher microscopic tests continue to indicate that the hard spots of corrugation have been heated to a red temperature or above the recrystallization temperature of the steel and become hard on cooling. Whether this can happen during short slides of car wheels as the brakes are applied is an unsettled question. Certainly short slips of locomotive drivers can cause corrugation, but we have no proof that such slippage occurs where corrugation has developed over long stretches of tangent track.

It has, however, been reported that on locomotives operating at high steam pressures, quarter flat spots have been developed on driver tires which are thought to be caused by slipping of the drivers during the first part of the cylinder stroke. This may be a clue to how corrugations are formed in long stretches at tangent track after many years of service. Any further information on the slippage of locomotive drivers would be of great value to the committee studying corrugations.

Chairman Bronson: Assignment 10—Engine burns—will be presented by Mr. Akers.

J. B. Akers (Southern): The report on Assignment 10 is a progress report and covers rolling-load tests being conducted at the Southern Railway laboratory at Alexandria, Va. To refresh your memory, this project has been going on for some time, being conducted with four rolling-load machines. One of them is a 7-in. stroke machine loaned by the Sperry Products Corporation; one a 12-in. stroke machine loaned by Union Carbide & Carbon; an additional machine purchased by AAR and recently placed in service; and still another in the laboratory of Metal & Thermit research laboratory is used.

So far 85 rails have been tested on the rolling-load machines. It takes a long time to do that work, at least a month; five or six weeks in some cases. Then, due to some other cause, such as a rust pit, you lose your entire work. The record of the rails tested shows the reasons for the failure, in each case. In this particular report we cover rails 38 to 85, incl. The report on the previous rails is in last year's proceedings. The results

as shown in diagrammatic form, Figs. 1 and 2, we do not think are conclusive, because they are all from noncontrol cooled specimens. I believe that is due to a previous fatigue, and the results are quite erratic in some cases.

Fig. 3 represents tests on the 7-in. stroke machine with control cooled rails intentionally engine-burned. But there are differences there in the amount produced. So, we do not think that Fig. 3 gives good results. Fig. 4 is the best criterion. That shows the summary for only a relatively few rails.

We think the test results obtained, although limited, appear to indicate a definite increase in fatigue life of engine-burned rails which have been repaired by welding, as compared to engine-burned rails unrepaired. There is admittedly considerable scatter in the results obtained in the welded rails which is believed to be due to variations in welding technique. Everyone recognizes the difficulties we face in that.

The committee proposes to continue these tests during the coming year and to augment them with further metallurgical examinations. This report is for information only.

President Chinn: Thank you, Mr. Akers. It will be so received.

Chairman Bronson: Assignment 11—Shelly rails—was the assignment of Mr. Hewes who had been very capable and highly successful in the handling of this difficult subject. Mr. Magee has kindly consented to present the report. At the conclusion of our complete report we will have addresses by Professor Cramer of the University of Illinois and Mr. Manning of Battelle Memorial Institute.

G. M. Magee (Association of American Railroads): This investigation on shelly rails is one of the most important now being sponsored by this committee, I believe I can safely say, and one of the toughest ones to be solved.

The first work, which was a rather thorough study made by the committee, involved the features that ordinarily you look for in trying to find the cause of a difficulty of this nature. These included studies of the location of the failures, by heats and by sizes of rail and by the position of the rail, and so forth. In none of these investigations was there any definite indication pointing to the cause of the difficulty.

In work undertaken by our Engineering Division research staff in the field, we made, several years ago, rather extensive measurements of the shape to which the head of the rail wears and the shape to which the wheel wears, with the thought that perhaps something could be done to remove the concentration of pressure that occurs on the gage corner of rail on curved track.

As a result of that, the modified test section of rail was rolled and placed in track on the Norfolk & Western Railway. This modified section appears to result in some lengthening of the period before shelling starts. As a result of this, the new 155, 132 and 133-lb. rail sections were given the modified top contour.

The principal effort, however, in the search for the cause of shelly rail is directed along metallurgical lines. The University of Illinois, under Professor Cramer, is doing work with rolling load machines, making comparative tests with various types of rail and heat-treated rail. In addition, Battelle Memorial Institute has been making an intensive metallurgical study, directed by George Manning, in an effort to determine whether any characteristic of rail steel can be found which appears to be the cause of the development of the shelling condition. We will have a report later from both of these men on the results of the investigation to date at those two institutions.

The report is presented as information, and it is intended to continue the investigation in the hope to find a solution to this difficulty.

President Chinn: Thank you, Mr. Magee.

Chairman Bronson: Assignment 12—Rail design—will be presented by Mr. Code.

C. J. Code (Pennsylvania Railroad): The report of Subcommittee 12 consists of a brief summary and two important supplementary reports on research projects: Appendix 12–a on the Effect of bolt spacing on rail web stresses within the rail joint, which will be presented by Mr. Magee, and Appendix 12–b on Fatigue tests of rail webs, which will be presented by Mr. Jensen.

For the second consecutive year, it has been the fortune of Subcommittee 12 that its work has been of such importance as to require action by the Association by letter ballot prior to the annual convention. Last year the new designs of rail sections were completed in the summer of 1946, and after recommendations, in turn, by this subcommittee and by the Rail committee, the designs were adopted by letter ballot several months in advance of the convention.

This year studies and tests made by Mr. Magee and his associates under the sponsorship of this subcommittee were reviewed by the committee in May and brought to a conclusion in early September. They were considered at a meeting of Subcommittee 12 on September 16. A recommendation was made to the Rail committee for the adoption of modified bolt hole spacing. The Rail committee considered it important to synchronize adoption of the revised bolt hole spacing with the placing of orders for new rail sections, and this resulted again in a request for letter ballot action. The request was granted, and the result has been reported to you by the subcommittee on revision of Manual.

Supplementing Mr. Magee's studies of stress are Mr. Jensen's studies of the fatigue of rail web steel.

Many of us, including myself, have in the recent past been accustomed to think of the failure of rails in terms of sudden blows producing stresses beyond the ultimate strength of steel. The traditional drop test of rail as called for by the specifications is in a sense an example of this conception of rail failure. Or, we thought of failure in terms of defective material, or defects such as the transverse fissure which may eventually result in sudden failure.

The conception of rail failure, where the metal is inherently sound, or as sound as modern metallurgy can make it, and where the stress at no time exceeds the ultimate strength of the material, is relatively new; yet that is what takes place in our web failures, both inside and outside the joint.

Studies of fatigue strength show us that steel in general, and rail web steel in particular can fail, due to repeated application of stresses far below the ultimate strength of the material, and considerably below the yield point. On the other hand, they show us that rail steel can withstand a good many thousand cycles and stress beyond the yield point without failure.

Field measurements of stresses, on the other hand, tell us that while we have many cycles of repeated stress in the track, many cycles of low stress, and a few cycles of high stress, we do not generally have enough cycles of high enough stress to cause in themselves the failures which we are experiencing. Further fatigue studies, introducing the factor of corrosion, show us that, with corrosion, the number of cycles of a given stress required to produce a fatigue failure is greatly reduced, and by combining the study of stresses in the field with corrosion fatigue studies in the laboratory we may come a good deal closer to an exact explanation of the failure.

Thanks to Mr. Jensen we now have some valuable data in the form of curves showing the fatigue strength of rail web steel with a range of stress from high com-

pression to low tension, such as we experience outside the joint on the low side of curves. We also have a curve for complete reversal from tension to compression of equal magnitude.

Much remains to be done. We have some corrosion–fatigue data for the range from low tension to high compression, but none for complete reversal as yet. We have no curves yet for conditions which apparently prevail inside the joint bar limits, that is, a range of stress from zero to high tension, low compression to high tension, or low tension to high tension.

Such data as we have for corrosion are for greatly accelerated tests covering a relatively short period of time. We would like to see some data for tests covering a longer period of time, and for ordinary corrosive media such as plain tap water, or water rendered slightly salty, or slightly acid.

The stress studies of Mr. Magee, and the fatigue studies of Mr. Jensen have progressed far toward explaining the cause of rail failures previously unexplained. We confidently expect that these studies in the near future will give us an explanation so exact as to leave no room for doubt as to the combination of stress and corrosion necessary to cause failure. It is only through the acquisition of such knowledge that we can arm ourselves with the necessary preventive measures to eliminate or reduce such failures to a minimum.

Two important preventive measures have been adopted in the strengthening of the web and the revision of the bolt hole spacing. I will ask Mr. Magee to present his report on Appendix 12–a.

Mr. Magee: With the adoption of the new rail section, it seemed very desirable to study the rail drilling so that any change found necessary could be made at once and avoid the highly objectional situation which would result if the drilling were changed after considerable mileage of rail of the new sections had been placed in track. Accordingly, the test work was expedited as much as possible.

A number of joints were obtained with three special drillings. The essential differences were: In the (A) drilling, the end hole was 1½ in. from the rail end; in the (B) drilling the end hole was 3½ in. from the rail end, and in the (C) drilling the end hole was 4½ in. from the rail end. Very complete strain gage measurements were made over the area of the rail web with these different hole spacings.

Some interesting facts were discovered from these tests. Tightening of the bolt seemed to be the principal factor in producing a high web stress within the joint bar limit. It was also found that the bars often did not fit the same on both sides, so that a bending of the web would result, and this even further increased the vertical stresses in web. Then, added to that, the mere fact that the hole was drilled in the rail web increased the stress concentration around the hole almost three times, so that we find a very high tension stress area around each of the drill holes in the rail.

Another high stress area, almost equally high, is encountered at the end of the rail, in the upper fillet, this being aggravated by irregularities that are formed in the fishing surface by the hot saws. Moving the end bolt hole back, as indicated in these tests, would appreciably lower the stress concentration at the first bolt hole and in the upper fillet at the rail end, at both of which areas fatigue cracks have developed in service.

From previous tests, it was known that, for efficient functioning of the rail joint, it was desirable to keep the middle holes fairly near the rail end. So we were faced with the necessity of deciding how far we could go in lowering our stresses and still space

the bolts close enough to insure efficient functioning of the joint. The (B) drilling which was recommended and adopted was, in our judgment, the best compromise we could effect to accomplish this purpose. This drilling has given us a substantial reduction in the stress in the first bolt hole and the upper fillet, and, rather strangely, according to our rolling-load tests, resulted in a rather substantial increase in the fatigue life of the rail joint.

Chairman Bronson: To complete our report, we will have two addresses on various research projects. We will hear from Mr. Manning of Battelle Memorial Institute, and then Professor Cramer of the University of Illinois.

(Professor Cramer presented synopses of the Fourteenth Progress Report on the Investigation of Failures in Rails (page 490) and of the Sixth Progress Report of Shelly Rail Studies (page 436.) Mr. Manning's remarks follow.)

Shelly Rail Study at Battelle Memorial Institute

By G. K. Manning

Battelle Memorial Institute, Columbus, Ohio

You may recall that last year several slides were shown which illustrated that, at least in some cases, shelly cracks may originate on the underneath side of the flowed over metal lip which clings to the gage side of the rail head. It was reasoned that this lip of flowed metal might act as a stress raiser and encourage the formation of a shelly crack on its underneath side. Some of the work during the past year was directed toward following up such an hypothesis and toward determining how important to shelling the formation of this lip is. For one thing, it was reasoned that, if the work-hardening rate of steel could be markedly increased, then the lip of flowed metal might never form on the gage side of the rail. For the most part, alloying elements do not markedly affect the work-hardening characteristics of steel. However, it is known that the nitrogen content and perhaps also aluminum content has some effect in increasing the work-hardening rate of low-carbon steel. Consequently several experimental heats of high-carbon steel were made to which had been added different amounts of nitrogen and aluminum. When these experimental ingots were cold-reduced various amounts, and tested for hardness, it was found that they all had substantially the same work-hardening rate and it was decided that this approach to the problem did not hold much promise. Tests were also conducted with shot peening to determine how much of an increase of surface hardness could be obtained and to what depth this work-hardened surface layer might extend. When it was found that shot peening for several minutes raised the surface hardness only a few points Brinell and that the increase in hardness was confined to a layer only 0.003 in. thick, consideration of such a procedure was abandoned.

A Test on the Pennsylvania

In May 1947, a test was initiated on the Middle Division of the Pennsylvania Railroad. Alternate rails in the high side of a 6-deg. curve were ground on their gage side sufficiently often to prevent the formation of any conspicuous lip of metal. This test is still going on. For the first two months it was necessary to grind the rail every two weeks, but at the end of two months, work hardening had occurred in the surface of

the rail to the extent that less frequent grinding was required. As a matter of fact, no grinding has been done since the end of the fourth month. The test has been going on for approximately 10 months now and to date no shelling has occured either in the ground rails or in the control rails. However, considerable light flaking has developed high up on the gage corner of both the ground and the unground rails. An interesting observation was made in this connection during the past few weeks. On the last inspection trip, it was noticed that this flaking instead of being worse than it was at the time of the previous inspection appeared to be wearing away and was less conspicuous. Upon inquiry, it was found that the curve oilers normally used on this curve have been out of order and out of use for a period of several weeks. This apparently bears out comments that I have heard other individuals make; namely, that the use of curve oilers so reduces the amount of wear which takes place on the surface of the rail that there is at least an apparent decrease in the amount of flaking which occurs.

The Norfolk & Western Railway has agreed to install another type of test. In this case, one group of 12 rails will be of standard specifications and serve as a control. A second group of 12 rails will be planed before being put into service so that the contour of the rail head will match the average contour of the wheels. It will be apparent to you that the idea embodied by this test is similar to that which led to the testing of the modified rail sections during the past few years. The difference is that in planing to the average wheel contour a considerably greater change is made in the contour of the rail head than was made in the modified sections. It probably would never be practical to roll rail having the same contour as the average contour of the wheels even though it were found that this would eliminate shelling. However, it is hoped that the results of this test will indicate whether additional work with modified head sections is likely to be fruitful. A third group of 12 rails for the N. & W. test are to be ground while in service in a manner similar to that now being tested on the Pennsylvania.

Shelling on Different Railroads

Recently we have been in the process of selecting some samples of shelling from the track of several different roads. During the past few weeks, several of you have been kind enough to accompany Mr. Blank on field inspections and to assist him in selecting examples of shelly rail from track. The samples so selected are removed from track and shipped to Battelle for further examination. From these samples, it is hoped that we will get a better understanding of the relative percentage of times that shelly cracks originate at the surface and the relative percentage of times the shelly cracks originate below the surface of the rail. We also hope that such examinations as these may enable us to subclassify shelly spots with respect to their probable cause. Particular attention is being given to obtaining specimens which exhibit just the first evidence of a shelly spot. It is hoped that we may be able to find some samples which contain very minute shelly cracks, and that from these we may obtain additional information about the mechanism by which the crack first develops.

We are also in the process of determining the residual stress which exists in the head of the rail taken from the high and low sides of a curve. It is hoped that the results of these tests will throw some light on the stress condition which results in shelling.

Discussion on Uniform General Contract Forms

(For Report, see pp. 123–134.)

(President Chinn presiding)

Chairman W. R. Swatosh (Erie): It is my sad duty to inform you of the loss that this Association and Committee 20 have suffered in the death of William Dollison Faucette at Norfolk, Va., on May 19, 1947. He had faithfully served as a member of this committee since 1916, or for more than 31 years, and during the years 1921 to 1926, incl., as its chairman.

He served with devotion, and his genial and friendly personality endeared him to all of its members. The contributions of valuable services and advice resulting from technical knowledge and long experience in important railroad, engineering, operating problems made him an invaluable member of this committee. We shall miss him, gentlemen.

Taking up the report of the committee, we had four subjects assigned and are presenting reports on all four. The committee will first report on Assignment 1—Revision of Manual.

Three forms have been reviewed, with a view to bringing them to a current basis, namely, Joint Passenger Terminal Agreement, Form of Agreement for Cab Stand and Baggage Transfer Privileges, and Form of Agreement for Joint Use of Passenger Station Facilities. Mr. W. G. Nusz will present the report.

W. G. Nusz (Illinois Central): As the chairman said, we were assigned three contracts for revision this year, which we carefully studied.

I first want to call attention to three corrections which should be made under Revision of Manual. The Manual pages should read in the first paragraph, 20–21 to 20–46. In the second paragraph, 20–48.1 should be changed to 20–46.1 and 20–48.3 should be changed to 20–46.3.

On the first assignment, Joint Passenger Terminal Agreement, after careful study we found three paragraphs we thought should be revised. The first is 802—Reserve for Retirement. No change was made in this paragraph except the insertion of the material underlined. The remainder of the paragraph remains as it is in the Manual.

I move the adoption of this paragraph as changed.

(The motion was seconded, put to a vote and carried.)

Mr. Nusz: A change is proposed in 803—Insurance—by inserting the underlined words. The remainder of the paragraph remains the same. This is to make it conform to changes in previous agreements.

I move the adoption of this paragraph as changed.

(The motion was seconded, put to a vote and carried.)

Mr. Nusz: The third paragraph, 1005—Payment in Legal Tender—is changed for the purpose of permitting legal tender of the United States instead of gold coin as now included in the contract.

I move this change be adopted.

(The motion was seconded, put to a vote and carried.)

Mr. Nusz: The Form of Agreement for Cab Stand and Baggage Transfer Privileges did not include any definition of the independent contractor. We propose a new Section 14 to be inserted in the contract, and renumbering the following sections: 14 to be

changed to 15, 15 to be changed to 16. This is for the purpose of identifying the contractor and showing that the company has no jurisdiction over him or his employees.

I move the adoption of this paragraph.

(The motion was seconded, put to a vote and carried.)

Mr. Nusz: The third assignment: Agreement for Joint Use of Passenger Station Facilities. After careful study of the contract, we found no change necessary.

I move that this form of contract be reapproved as now contained in the Manual.

(The motion was seconded, put to a vote and carried.)

Mr. Nusz: That completes the report of Subcommittee 1.

President Chinn: Thank you, Mr. Nusz.

Chairman Swatosh: The next is a report on Assignment 2—Form of construction contract for minor projects. This form was presented as information at the last convention. It has been thoroughly reviewed, with particular emphasis being applied to the development of an adequate liability, permit, license and insurance clause. The report will be presented by Mr. L. A. Olson.

L. A. Olson (Pere Marquette): We drafted this Form of Construction Contract for Minor Projects in order that we might have a shorter form than the long form which appears in the Manual. It turned out to be fairly long in itself, by the time we got in all the requirements for insurance and everything else.

The contract itself can be used, I believe, for something a little beyond minor projects, as well as for the smaller projects.

(He then read the paragraph headings, and his motion for the adoption of the form of contract was seconded, put to a vote and carried.)

Mr. Olson: That concludes the work of Subcommittee 2.

President Chinn: Thank you, Mr. Olson.

E. M. Hastings (Richmond, Fredericksburg & Potomac): I do not wish to discuss the report; purposely refrained from that until the motion was carried.

I would like to ask the secretary, if there is sufficient demand following the publication of this in the Manual, if these forms will be printed so that they will be obtainable by the carriers as was the long form of construction contract.

Secretary Lacher: It would be pretty hard to say. We probably would have to make inquiries of the railroads to find out.

Chairman Swatosh: The next report is on Assignment 3—Form of agreement for construction of stop log or other structures for flood control. Plans for major flood control projects throughout the United States are originated by army engineers. In a great many instances, these plans permit railroad tracks to remain at their established grade through the flood projection system. It is axiomatic that all gaps and openings so provided should be sealed during flood stage. The installation of such openings generally involves construction of concrete sills through the railroad roadbed.

It has been found practical and expedient, where such sills are to be constructed to have the government's contractor enter into agreement with the railroad to cover, at the sole cost and expense of the contractor the supporting of its tracks during the construction of the sills. Accordingly, your committee has developed a form of agree-

ment for such purpose. The form developed is one of several being prepared by the committee to cover various phase of work to be done by railroads in connection with flood control. The report will be presented by Mr. G. W. Patterson.

G. W. Patterson (Pennsylvania): As the chairman has explained to some extent, the need for such an agreement was brought about through the placing of responsibility on contractors by the government or other flood control agency to enter upon the right-of-way of a railroad for the purpose of constructing a stop log or other flood control structure, which construction might endanger the railroad tracks or other facility.

(He read the paragraphs headings.)

Mr. Patterson: Because of the current need of such a form of agreement, your committee presents this draft with a recommendation that it be adopted and published in the Manual. I move that the agreement form be adopted for publication in the Manual.

(The motion was seconded.)

President Chinn: You have heard the motion. Is there any discussion?

M. A. Roose (Southern): At the top of page 131 you refer to the "War Department, Corps of Engineers." Under the new unification of the armed services, I think that should be the "Department of the Army."

Mr. Patterson: I agree with that. There has been a recent change. That correction should be made.

President Chinn: Mr. Patterson, I would understand you accept that suggestion?

Mr. Patterson: Yes, sir.

(Mr. Patterson's motion, including the suggested change, was then put to a vote and carried.)

Mr. Patterson: That completes the report on assignment 3.

President Chinn: Thank you, Mr. Patterson.

Chairman Swatosh: The last report is on Assignment 4—Form of agreement to permit subsurface exploration by state or other governmental agencies, on railway right-of-way.

It has been found that governmental agencies require entry on railway right-of-way to make subsurface explorations so they can properly design foundations for structures. Experience discloses that the most desirable method of handling such entry and giving these agencies the right to make these explorations is by written agreement.

Your committe has therefore developed a form of agreement for such purpose. Mr. Montville of the Nickel Plate Railroad was to present the report but he is not present this morning. I will present the report in his stead.

The agreement is self-explanatory. The committee submits the tentative draft of agreement as information. This completes the report of Committee 20, Mr. President.

President Chinn: Thank you, Mr. Swatosh.

Mr. Swatosh, because of the valuable work which your committee has done through the years, most of us have assumed that there is not much left for you to do but to keep the previously adopted contract forms up to date. However, it is a matter of no little gratification to us to learn that during the past year you have developed certain new documents to meet current requirements.

Your committee is excused with the thanks of the Association. (Applause)

Discussion on Records and Accounts

(For Report, see pp. 307–322.)

(President Chinn presiding)

Chairman F. B. Baldwin (Atchison, Topeka & Santa Fe): The report of the subjects considered by your Committee on Records and Accounts seems to be affected by the fact that so many engineers are engaged in the work represented by the assignments of this committee.

In addition to the personnel of the committee, there are hundreds of engineers on railroads all over the country connected with the making and keeping of property records, and under present-day conditions, with respect to heavy taxes and the narrow margin between the limit of income and high wages and material prices, these engineers must necessarily understand the importance of rules of accounting and guard against loose and improper use of those rules.

Modern engineers, if they are to serve the best interest of the railroads, must familiarize themselves with the effect of the proper application of the accounting rules, in order to be competent, to cooperate fully with the accounting departments. Today we see many engineers serving as accounting officers. Some of them are on this committee.

Your committee has seven assignments, on six of which it has reports of progress or information.

The report on Assignment 1—Revision of manual—will be presented by Mr. J. B. Mitchell, chairman of the subcommittee.

J. B. Mitchell (Great Northern): The committee recommends reinstating in the Manual a page containing data regarding sizes of sheets for engineering drawings, forms and charts; a page containing designation for taper, batter, cant, slope, incline and grade; and also recommends placing in the Manual, reference to a publication of American Standards Association pertaining to mechanical drawings and graphical symbols. There are also three minor corrections.

I move the adoption of the report.

(The motion was seconded, put to a vote and carried.)

Chairman Baldwin: The second assignment is: Bibliography on subjects pertaining to records and accounts. The report on this assignment will be given by Mr. V. H. Doyle, chairman of the subcommittee.

V. H. Doyle (Chesapeake & Ohio): As in the past years, we have attempted to list, for the benefit of the members of the Association, the latest books, articles and pamphlets on the subject of railroad accounting, valuation and depreciation, so that it will be available for anyone who has to familiarize himself in a hurry with any phases of that subject, and the latest developments.

President Chinn: Thank you, Mr. Doyle. The report will be accepted as information.

Chairman Baldwin: Assignment 3 is in two parts. The general heading is: Office and drafting practices. Under the first part—Organization; duties and nature of assignments—the committee has no report, but I would like to say that this has been a subject of very much discussion in the committee. It has not been possible to make any progress on this part of the assignment, largely because of the press of other seemingly more important duties of the committee members, but also partly because of the indefinite nature of the assignment.

The subject was originally assigned, at the suggestion of the chairman, as a vehicle for presenting to the younger members of the Association and to other young engineers

who might be contemplating service with the railroads, some idea of how the engineering departments on railroads are organized, what the various positions in that department are, and what the duties and nature of assignments are that go along with those various positions. It was the thought that a report of this kind, covering all positions from the chief engineer down to chainman, would give a better understanding of the railroad organization to the beginner and to those who might be considering a career in railroad engineering.

It is believed that a report of this nature might be supplementary or complimentary to the subject that is being studied by Committee 24, from which we had a very excellent report day before yesterday. It was not the purpose of this assignment to attempt to design an organization or to recommend an ideal engineering organization; neither was it the purpose to analyze, or criticize any existing organization. The committee will be glad to have any suggestions from members of this Association on this subject.

The second part of the assignment—Modern mechanical drafting aids—is a continuing assignment for the committee, but this is the first report on the assignment for several years.

About a year ago the word "photogrammetry" became a new word in the vocabulary of many of us, and the report this year has a section dealing with that branch of the science. The report will be presented by Mr. W. M. Ludolph, chairman of the subcommittee.

W. M. Ludolph (Chicago, Milwaukee, St. Paul & Pacific): The report on modern mechanical drafting aids describes a number of mechanical drafting aids which have been in use in various engineering drafting rooms. These are as follows: Photogrammetric instruments; pencil tracings; vapor developed prints; prints developed with special developer; machines for exposing sensitized paper; reconditioning drafting tables; lettering guides; lettering machines; illumination; filing equipment; improved blueprint paper.

Most of these aids have been in use for a number of years, although most of them were not widely used. On account of the urgency of preparing maps in connection with the war effort, greater use was made of photogrammetry than ever before, and the use of other aids was also accelerated by the war.

This is a final report and is submitted as information, with the recommendation that the subject be reassigned after a number of years, when new developments make such a report desirable.

President Chinn: Thank you, Mr. Ludolph. The report will be accepted as information.

Chairman Baldwin: Assignment 4 is headed: Statistics for railway maintenance; operation and construction. This has proved to be a very difficult subject because it requires much study, time for which has been lacking on the part of the committee members during the past year. Engineers on a few railroads have developed the statistical approach to their problems of maintenance and operation, to a point where apparently much benefit is experienced. To a large extent, however, the statistical features have been considered as an accounting problem and have little practical use to the maintenance or construction engineers.

The purpose of this assignment is to develop the subject of engineering statistics and suggest ways of accommodating statistics to the maintenance or construction engineer's needs. The committee hopes to make some progress on the subject during the coming year.

Assignment 5—Construction reports and property records; their relation to current problems. The report will be presented by Mr. W. C. Bolin, chairman of the subcommittee.

W. C. Bolin (Baltimore & Ohio Chicago Terminal): To a highly technical engineer, construction reports and property records are a bothersome detail to be shunted where possible onto a poorly trained clerk or assistant, to struggle with the best that he can, usually while burdened with enough other duties to sink a ship.

The construction engineer, who gives inadequate attention to his reports, should not be surprised on having his attention called to the extremely high unit construction costs incurred on his project. The total costs pertaining to the project will, in all probability, be charged to the project. Failure to report all of the units properly, such as rock, loose rock or hardpan excavation instead of common; heavier or deeper foundations; richer concrete or heavier reinforcing, which cannot be detected after the work is completed, produces high unit costs. While being a good fellow and helping other departments, within reason, is meritorious, be sure and report all the work performed for other departments, or you may find yourself behind the eight ball, when the unit costs of your project are compared with that of your fellow engineer on a similar project.

The maintenance engineer, with construction projects in progress on his territory, should be alert to report properly all work that he performs for the construction department; and, as far as possible, he should scrutinize operation charges assessed against his budget arising from the construction project.

The accounting rules of the ICC prescribe in great detail just how the accounting is to be performed, and there is litle likelihood of improper accounting, of consequence, where the prescribed routine is faithfully observed. I will not bore construction and maintenance engineers with any comments on the vexatious prob'ems encountered by valuation and statistical engineers, as well as accountants, in transcribing the field reports onto the books of the company and then onto the detailed and complicated forms required to comply with ICC requirements, and make the reports of value for every purpose. I would say in passing, however, that there is a great shortage of engineers with accounting training and of accountants with engineering sense.

Seniority rules make it very difficult for a talented accountant with horse sense along engineering lines to emerge from the rank and file of clerks and secure a supervisory status before he is so burdened with seniority that he is no longer adaptable to a position where thinking is the essential requirement. Of necessity, young graduate engineers with accounting training must be looked to for replacements in executive positions.

This committee in its report of last year (see Proceedings, Vol. 48, 1947, pages 407–408) very briefly directed attention to a few of the current problems which can be solved only by consideration of the statistics which have as their basis the value of the property. The underlying data for every valuation statistic is the original construction report and property record.

Freight and passenger rates; the financing of stocks and bonds; all trackage arrangements with other roads; rentals for leased property; depreciation for income tax purposes; the taxable value for state and local taxes and the allocation of that tax down to the smallest school or special tax district are determined from the mileage, property and valuation records of the company. To the extent that statistical, valuation, construction and maintenance engineers participate in the determination of valuation, to that extent, at least, they are participating with the company executives in solving the current railroad problems.

This is offered as information.

President Chinn: Thank you, Mr. Bolin, for an interesting statement.

Chairman Baldwin: Our next assignment, 6—Valuation and depreciation—has three parts, and the subcommittee presents a report on the first portion: Current developments in connection with regulatory bodies and courts. The report will be presented by Mr. H. T. Bradley, chairman of the subcommittee.

H. T. Bradley (Missouri Pacific): As stated by the chairman, the report of this committee is limited to Assignment 6 (a): Regulatory bodies and courts.

That part of the report relating to regulatory bodies is confined to activities of the Interstate Commerce Commission and its Bureau of Valuation. The filing of 588 returns by Class I carriers is on a fairly current basis and has been the last several years.

The Bureau of Valuation is now engaged in bringing valuations from 1932 down to date at 1910–1914 prices by the so-called long form method. This method involves estimating depreciation by individual classes of property, which is not done on the so-called short form method. On October 1, 1947, this work was approximately 73 percent complete. Carriers have been asked to cooperate in this work, which affords them an opportunity to check the Bureau's figures and secure carbon copies of the detailed pencil sheets.

In Ex Parte No. 166—Increased Freight Rates, 1947—the Bureau of Valuation filed Exhibits 20 and 21 showing elements of values for all Class I line-haul railways, by districts and regions, as of January 1, 1947.

At the hearing in December 1947, Exhibit 108 was introduced, showing the same elements of value by individual carriers. The cost of reproduction new for all Class I line-haul carriers included in these exhibits was approximately $32,600 million, and the cost of reproduction less depreciation was $20,650 million, which indicates a composite percent of cost new of 63.328. This low percentage is due largely to equipment, the percent of cost of new equipment being 48, which carriers were unable to replace during the war years.

The period price level used by the Bureau for determining cost of reproduction new was about 178 percent of the 1910–1941 level, or an approximate average of the ten years 1937–1946. I might say this was an ultraconservative period price. If a spot index for the year 1947 had been used, the cost of reproduction new would have been about $46 billion. The estimated original cost of these roads was $24 billion.

From these figures, it is obvious that depreciation accruals based on original cost of $24 billion are entirely inadequate to make replacements at current prices which would require $46 billion to reproduce the property.

The aggregate value of carrier lands found by the Bureau as of January 1, 1947, was $1,935 million which is $800 million less than the value found by them at the bottom of the depression in 1932, and $1,500 million less than that found in 1929.

The bulk of these land values, possibly 60 percent, is found in our larger cities, and it is here that the greatest losses have occurred. This is attributed by the Bureau to the so-called blighted areas and slum districts which have grown up around railroad property. Possibly this picture has been somewhat overdrawn.

With respect to court decisions, there were two cases decided in lower courts which may afford some indication of judicial thought about rate-making bodies. These cases

are Marietta v. Public Utility Commission, et al, decided by the Supreme Court of Ohio on June 24, 1947, and the Staten Island Edison Corporation v. Milo R. Maltbie, et al, handed down by the New York State Court of Appeals on May 22, 1947.

The Ohio decision supports the use of cost of reproduction less observed depreciation for determining the value of the property other than land, even when no consideration was given to original cost.

In New York the court found that a return on a rate-making value based on original cost less depreciation might be confiscatory, and that even findings of fact by regulatory bodies are still subject to judicial review.

This report is given as information.

President Chinn: Thank you, Mr. Bradley.

Chairman Baldwin: The last assignment, 7, of the committee is: Changes in, revisions, and interpretations of ICC accounting classifications. A subcommittee report will be presented by Mr. H. D. Barnes, chairman of the subcommittee.

H. D. Barnes (Chicago & North Western): While the subcommittee's report for the past year contains references to several orders and interpretations issued by the ICC during the year, most of these are of limited interest to engineers.

Th reversal of a previous decision in ICC Docket No. 29140, made just prior to the 1947 convention, is probably the most important. It has now been decided that expenditures for driving posts and for pressure grouting to arrest water pockets and mud heaves are properly chargeable to operating expenses.

On March 10, 1948, the ICC announced the appointment of Dr. Ford K. Edwards as director of the recently reorganized Bureau of Accounts and Cost Findings, to succeed Mr. C. D. Crandall who retired on February 29. Dr. Edwards had been head cost analyst of the Bureau of Transport Economics and Statistics.

This report is submitted as information, with the recommendation that the subject be continued.

Chairman Baldwin: Mr. President, that concludes the report of Committee 11—Records and Accounts.

President Chinn: Mr. Baldwin, the report of your committee gives evidence of painstaking work in a highly specialized field of railroad engineering. We are very much indebted to you and your committee for furnishing us with a fund of valuable information relating to your special committee. Your committee is now dismissed with the thanks of the Association.

Discussion on Waterproofing

(For Report, see pp. 145–146.)

(President Chinn presiding)

Chairman G. E. Robinson (New York Central): This year's report of the Waterproofing committee is concerned entirely with the routine revision of the Specifications for Bituminous Emulsions for Dampproofing. Only a few changes were found to be necessary.

(He read the report on Assignment 1.)

Chairman Robinson: The essential difference between the specification as it stood and as it is now proposed is that we have taken out the application of asphalt to steel, on the theory that that is a matter of paint and does not belong in the waterproofing section.

I move that the proposed changes in the Manual be adopted.

(The motion was seconded, put to a vote and carried.)

Chairman Robinson: Last year the Waterproofing committe requested some funds for research in the matter of waterproofing materials, and the Masonry committee also requested some funds to be spent in research on the causes of deterioration of concrete. The Board of Direction saw fit to combine these into one project. I take pleasure in introducing Mr. G. M. Magee, the genial head of our research deparmtent of the AAR.

G. M. Magee (Association of American Railroads): As Mr. Robinson has told you, we have these two projects for the Masonry and Waterproofing committees that really are closely associated, because, on the one hand, we have the surface deterioration of concrete, and on the other a study of various waterproofers for the purpose of preventing this surface deterioration.

In endeavoring to progress the project, we decided that we would employ a concrete assistant, Mr. B. L. Robinson, on our research staff, to make comprehensive field studies of deteriorated concrete. We felt that we needed someone to consult with and advise us on the technical aspects, who was quite expert on these matters.

In discussing this with various individuals, I talked to Professor Huntington at the University of Illinois and asked him if he could make a recommendation. He said he had a recommendation to make which might surprise me a little bit, but that Dr. Ruth Terzaghi had lectured at the University of Illinois several times on this subject, and they had been very much impressed with her knowledge of the subject.

Accordingly, I contacted Mrs. Terzaghi and was very pleased to find that this was a subject in which she was interested. I feel sure, after you hear her speak, you will realize that we are very fortunate in having been able to secure her assistance on this investigation.

Mrs. Terzaghi is a graduate of the University of Chicago where she secured her Bachelor of Science and Master of Science degrees. She received her Doctor's Degree at Radcliffe, which she tells me is the girls' portion of Harvard.

She taught geology at Goucher and Wellesley Colleges for three years, following her training. As you perhaps know, she is the wife of Dr. Carl Terzaghi who is the international authority on soil mechanics. She has been associated with Dr. Terzaghi in the examination of damsites in Russia, North Africa, Central Asia and Mexico for a period of several years.

In connection with her consulting work, she has had occasion to investigate grouting problems and concrete deterioration in several instances. She has also presented numerous papers on petrographic subjects and several on concrete deterioration. At the present time she lectures on concrete deterioration in the Graduate School of Engineering at Harvard and also at the University of Illinois.

I am pleased to present Mrs. Terzaghi. (Applause)

Concrete Deterioration

By Dr. Ruth D. Terzaghi

Introduction

Engineers all over the country are becoming aware of the fact that concrete is not necessarily a permanent building material, even when the raw materials and the methods of manufacture and placing conform to the best modern standards. As a result of this growing realization, the deterioration of concrete has, after many years of suppression, finally become a respectable and popular topic of discussion. The American Concrete Institute even devoted an entire session to this subject at its recent annual convention in Denver.

Dissatisfaction with the Old Dry Mixes

This is not the first time in the history of concrete technology that engineers have become acutely aware of the need for better concrete. At the turn of the century, there was a wave of dissatisfaction with the dry mixes and honeycombed concrete then in fashion, and specifications were finally written which required the use of so much water in the mix that the water would rise freely to the surface.[1] This procedure was confidently expected to result in concrete of improved quality, and deterioration of concrete placed during the preceding dry period was unhesitatingly ascribed to the small quantity of water in the mix.

The New Dry Mix

As the wet mixes finally began to succumb to time and the weather, some engineers must have begun to question the wisdom of the wet mix. At the same time, the important effect of water-cement ratio and grading of aggregate on strength began to receive widespread attention. Finally, concrete technologists ruefully, perhaps, returned to the dry mix. However, there was to be one big improvement over the old-fashioned dry mix. Concrete was to be dense as well as dry.

The new theories of concrete mix design bore valuable fruit in the shape of greatly increased strength and uniformity of concrete, and concrete technologists again felt optimistic. Failure of concrete placed during the preceding wet period was now readily explained as a result of the excessive quantity of water used in the mix, and deterioration became firmly associated in the engineering mind with high water-cement ratio and/or low density. It was considered evidence of improper practice of one kind or another. Hence all cases of deterioration were blushingly concealed, and even the words "concrete deterioration" were rarely spoken in public. Unfortunately this discretion made no impression on the destructive agents at work on concrete, and it is now becoming apparent that these agents can, under some circumstances, destroy concrete which conforms to the highest modern standards. Some engineers even go so far as to say that the best modern concrete is less durable than concrete placed many years ago.

Air Put Back Into Concrete

Now the question arises, what should be done to increase the durability of concrete? We have tried dry, porous mixes. We have tried wet, non-porous mixes. These were discarded in favor of dry, non-porous (i.e. "dense") mixes. Deterioration has survived all of these changes. Now it appears that another change is about to take place. We are

[1] AREA Manual of 1905, p. 50.

going to use air entraining agents to put back the voids which we have been conscientiously eliminating, chiefly by means of careful gradation of the aggregate. If history hasn't quite closed the circle, at least it has brought us 360 deg. around a spiral, back to a dry porous mix.

Perhaps the dry porous mix produced by means of an air entraining agent is the solution of all, or at any rate, of many of our problems. Certainly the consistently spheroidal air voids introduced by air entraining agents have at least one advantage over the irregular, more or less continuous voids which are common in the concrete placed in the first "dry" period. This advantage lies in the fact that the globular air voids do not increase the permeability of the concrete, whereas the presence of more or less continuous voids is certain to result in high permeability.

What Makes Concrete Durable?

If our faith and optimism are unbounded, we can accept air entrainment with the same enthusiasm which has greeted earlier innovations, and we can wait patiently 20 or 30 years to find out whether or not our enthusiasm is justified. In the meantime, we can attribute deterioration to low air content. However, some of us are not optimistic by nature, and we incline to Mark Twain's definition of faith as believing what you know isn't true. To such skeptics, one course seems to be open. It is based on the following reasoning: Some of the concrete placed 40 or 50 years ago, or even more, is still in excellent condition. As thorough-going skeptics, we want to find out, first of all, did this concrete endure because of some happy accident of a favorable, protected location, or did it endure in spite of exposure as rigorous as that which may cause the failure of modern concrete? If we can rule out the happy accident as a factor in survival, the next step is to discover in what respects the durable concrete is superior to the less durable. We must also attempt to determine what specific processes are causing the deterioration of modern concrete, and what characteristics of this concrete have rendered it particularly susceptible to those processes. These discoveries will not be easily or quickly made. However, so many problems, both in concrete technology and in other fields, have yielded to systematic study of this kind, that optimism as to the outcome of such an investigation is amply justified.

AAR Research Program

As Mr. Magee has told you, the Association of American Railroads has decided to take the course which I have outlined, and a research program on concrete deterioration has been set up under his general direction. At least in the early stages, this program will consist essentially in the inspection of concrete structures, including some in perfect condition, as well as many on the way to failure. In examining the latter, we shall have to bear in mind the fact that many different processes, either combined or singly, may lead to the deterioration of concrete. The remaining time will be devoted to the most important of these.

Causes of Rapid Deterioration

Some types of deterioration are acute and lead to relatively rapid failure. Like the acute diseases of organisms, these have received widespread attention and are relatively well understood. Among the most important of these are deterioration due to chemical attack by waters containing either sulfates or carbonic acid or both. The rate at which this kind of deterioration takes place varies with the permeability of the concrete. We should therefore expect that present-day, dense concrete with a low water-cement ratio should be more resistant to attack by aggressive water than older con-

crete, because the permeability of modern concrete is in general lower than that of older concrete. Modern concrete is however not immune to such attack; it only succumbs more slowly.

Another type of acute and generally rapid deterioration is due to a reaction between certain kinds of aggregate and the alkalis (potash and soda) contained in the cement. In the past seven or eight years, the deterioration of many concrete structures has been attributed to this reaction. In this connection, an important question arises. Was this type of deterioration almost unknown before 1940 because it rarely took place, or was it unknown merely because its effects were not recognized? If the alkali–aggregate reaction was in fact uncommon in structures built more than 10 or 15 years ago, we must ask one further question. Did the older cements fail to react with the kinds of aggregate now known to be "reactive," or were such aggregates, by some happy accident. avoided until quite recently?

Deterioration Due to Unequal Volume Changes of Constituents

In addition to the spectacular ailments of concrete previously discussed, we have to consider the numerous processes which contribute to the relatively slow deterioration of concrete exposed to the weather. Such deterioration is considerably more difficult to diagnose because many of these processes operate almost universally wherever there is weather.

In order to understand the effect of weather on concrete, we must remember that concrete, like a committee, is composed of a large number of individuals, each of which behaves according to its own habits and laws. If these individual constituents differ too much from one another in their behavior, the concrete is likely to deteriorate. When we speak of the behavior of the constituents of concrete, we refer chiefly to volume changes due to variations in temperature and moisture content. The constituents which must be considered include the hydrated cement (or paste), the fine aggregate, the mortar, consisting of paste plus fine aggregate, the coarse aggregate, and free, freezable water located in pores and cracks in the concrete. We shall discuss the volume changes of each of these in turn, and finally the effect of the various individual volume changes on the concrete as a whole.

Volume Changes of the Paste

The volume of neat cement changes notably with variations of temperature and moisture content. If the temperature decreases 100 deg. F., the linear contraction of neat cement is commonly from 0.08 to 0.1 percent of the length (Hatt 1925, Myers 1935). When it dries out for the first time there is an additional linear contraction of 0.2 (Hatt and Mills 1928) to 0.4 (Campbell and White 1906) percent. If drying shrinkage is superimposed on thermal contraction, the total length decrease is 0.28 to 0.5 percent. If dessicated neat cement becomes saturated, its length may increase by as much as 0.17 percent (White 1911). If its temperature is simultaneously raised by 100 deg. F., there is an additional length increase of about 0.1 percent. The total linear expansion is then nearly 0.3 percent. After repeated cycles of wetting and drying, the length changes due both to wetting and to drying commonly decrease, and they may be reversible—that is, expansion due to saturation is approximately equal to contraction due to drying. According to White (1911) these reversible changes may amount to as much as 0.1 percent of the length. Hence neat cement bars which have been subjected to numerous cycles of wetting and drying may repeatedly undergo a decrease or an increase in length of as much as 0.2 percent if periods of saturation coincide with periods of high temperature and periods of drying coincide with periods of low tem-

perature. If changes of this magnitude take place in an unrestrained bar, they have no ill effects. If however the bar is restrained at the ends, tension develops during contraction and the bar cracks. Similar restraint is produced if the neat cement bars contain particles of any substance which does not undergo similar volume changes. If the expansion of these particles exceeds that of the neat cement, they will tend to split the cement during periods of expansion. If their contraction is less than that of the neat cement, the same effect will be produced during periods of contraction. Since all types of aggregate have a lower coefficient of thermal expansion than neat cement, and their volume does not change appreciably upon wetting and drying, the paste contained in mortar and concrete is subjected to tension whenever it contracts owing either to decrease of temperature or to loss of moisture.

Effects of Unequal Volume Changes

Under favorable circumstances, the paste may not suffer noticeably from the application of tension associated with drying or cooling. These favorable circumstances include low water–cement ratio which reduces the amount of contraction due to drying, and the presence of fine aggregate consisting of quartz, which has a coefficient of thermal expansion nearly as great as that of cement paste. On the other hand, if the mortar has a high water–cement ratio contains fine aggregate with an unusually low coefficient of thermal expansion, the paste may be subjected to excessive tension if it is exposed to repeated cycles of wetting and drying and heating and cooling.

If the fine aggregate particles consist of homogeneous grains of certain minerals other than quartz, the effects of tension may be particularly notable, because the linear thermal expansion of these minerals varies markedly with the crystallographic direction. If, for instance, we cut a cube from a crystal of calcite (the chief constituent of limestone) in such a way that the so-called c-axis of the crystal is at right angles to two of the faces of the cube, we would find that the four edges of each of those two faces would grow longer when the cube is cooled, and shorter when it is heated. The other four edges of the cube would change in a normal way, that is, they would grow shorter when cooled and longer when heated. If the particles of fine aggregate in a mortar behave in this fashion, we can hardly expect the paste to maintain its strength and integrity if it is subjected to successive cycles of extreme heating and cooling. This is perhaps the explanation of two recent cases of deterioration of concrete in which both coarse and fine aggregate were calcareous material, probably consisting chiefly of calcite.

Unequal Volume Changes of Mortar and Coarse Aggregate

If we consider the concrete as a whole, we encounter a similar problem of unequal volume change of mortar and of coarse aggregate. If the coarse aggregate consists of quartzite or of sandstone, the inequality of volume change is reduced to a minimum, because these rocks invariably have a coefficient of thermal expansion which is close to that of mortar (sandstone 5×10^{-6}, quartzite 6×10^{-6}, and mortar 6 to 7×10^{-6} per deg. F.). Hence, if the water–cement ratio of the mortar is low, the difference between the volume change of the mortar and that of the coarse aggregate does not exceed the maximum compatible with durability. On the other hand, other rocks commonly used as coarse aggregate, including some igneous rocks and some limestones, may have a coefficient of thermal expansion as low as 2×10^{-6}, which is much lower than that of mortar. The use of such rock as coarse aggregate may lead to deterioration, as a recent investigation by Sweet and Woods (1948) in Indiana has shown.

Now the question arises, is deterioration the inevitable result of unequal volume changes of paste and aggregate? We do not yet have sufficient information to provide

a complete and accurate answer to this question. However, observations which we have made thus far on railroad structures suggest that the effect of these volume changes may be less severe if the concrete is porous than if it is dense. In this connection, the condition of a concrete box culvert near Denver is of particular interest. The coarse aggregate in this structure consists almost exclusively of stream gravel with a particle size between ⅜ and ¾ in. Except in one place in the structure, the aggregate particles are cemented together only at the points of contact—in other words the concrete consists almost entirely of honeycomb. The structure is in perfect condition except in the one place where the voids between the coarse aggregate are entirely filled with mortar. This relationship is not quite in accord with our classical theories of concrete mix design. However, it is not surprising if we remember that mortar limited to the points of contact of coarse aggregate is subject to relatively little restraint. It is free to expand and contract with changes in temperature and moisture content. On the other hand, mortar which completely fills the voids between the coarse aggregate must crack if its contraction is notably in excess of that of the coarse aggregate.

Disruption of Concrete by Frost Action

Thus far we have discussed the disruptive effects of unequal volume changes of the solid constituents of concrete. All of these changes amount to only a fraction of one percent, expressed as a change of length. In concrete subject to freezing temperatures, the pore water may undergo a much greater volume change. If the water is not free to escape as freezing progresses, disruption of the concrete takes place. Several circumstances have focused so much attention on this volume change that it has generally "stolen the show" from other destructive processes. Among these circumstances are the magnitude of the volume increase (about 10 percent of the volume of the liquid), the familiarity of certain obvious effects of the expansive force of freezing water, such as broken milk bottles and ruptured water pipes, and finally the vast amount of work which has been devoted to the study of the effects of freezing temperatures on concrete. The combined psychological effect of these circumstances has been so overwhelming that deterioration of concrete in a given region is commonly attributed without hesitation to frost action merely on the basis of a statement by the weather bureau that the temperature is known to drop below 32 deg. F. in that region. Such a diagnosis may give the investigator a satisfactory feeling of "mission accomplished," but it does not contribute to an understanding of the nature and causes of concrete deterioration.

On the other hand, it must be admitted that we do not yet know the specific diagnostic symptoms of deterioration due to frost action under field conditions. If we could learn to recognize these symptoms, we would be well along on the road to learning how frost affects concrete. This step would constitute an important advance toward learning how to make concrete immune to the effects of frost under field conditions.

Need for Field Observations

In conclusion, I wish to add that the problems connected with concrete deterioration are so diverse, and involve so many variables, that they will hardly be solved by the unaided efforts of a few teams of investigators working under the auspices of various organizations like yours. These teams will need the active cooperation of every one who has anything to do with concrete. Those of you who can watch a set of structures year after year, in all seasons and under all conditions, have an opportunity to learn facts about concrete deterioration which is denied to those of us who make flying visits to a large number of structures. We have never seen these structures before. Many of them we shall never see again. We don't know when deterioration started, or what the

first manifestations were. We don't know how fast deterioration progressed once it got started and we can only guess how rapidly it will continue in the future. These gaps in our knowledge can be filled only by the men who spend years with a single group of concrete structures.

One more point I would like to emphasize. There are no experts in this field. All any of us have is a notebook, a pair of eyes, reinforced perhaps by a hand lens, and a lot of curiosity. If a large number of us will use these articles, we should be able to solve some of our problems. When we get them all solved we shall all be experts, but concrete will have become totally uninteresting.

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President Chinn: Thank you, Mr. Robinson, for the report of progress presented by your committee. We are all very much interested in the research work that has been sponsored by your committee and in the thought-provoking address by Dr. Terzhaghi.

Your committee is now excused with the thanks of the Association. (Applause)

Discussion of Track

(For Report, see pp. 323–371.)

(Vice-President Mottier presiding)

Chairman E. W. Caruthers (Pennsylvania): During the past year the Track committee has suffered the loss of a valued member in the death of Littleton Hewitt Roden. A biographical sketch is recorded in the report of the committee.

Nine subjects were assigned to the committee for study during the past year. Progress in the work on three of the subjects did not warrant the preparation of reports, but reports will be presented on six of the assigned subjects. Further progress has also been made in the research projects now under way, and Mr. Magee, the research engineer, will review this work.

The report on the first assigned subject will be made by Mr. Strattman, chairman of the subcommittee on revision of Manual.

C. R. Strattman (New York Central): Your committee offers for reapproval without change, the following text now appearing in the Manual.

Pages 5–15 and 5–16—Specifications for Soft Steel Cut Track Spikes.
Page 517—Design of Cut Track Spikes.
Page 5–18—Table of Temperature Expansion for Laying Rail.
Page 5–19—Oiling Track Fixtures.
Pages 5–44 and 5–45—Vertical Curves.

I move the reapproval of these without change.

(The motion was seconded, put to a vote and carried.)

Chairman Caruthers: On the second assigned subject—Fastenings for continuous welded rail, collaborating with Committee 4—a progress report will be made by Mr. A. L. Bartlett, who is chairman of the subcommittee.

A. L. Bartlett (New York, New Haven & Hartford): We were to determine the justifiability of the type or types of fastenings suitable for continuous rail, together with the proper anchorage. We have assembled considerable data on installations and have made some inspections. In addition, we have constructed a 1200-ft. test track at New Haven, with 131-lb. rail in stone ballast, which has been under observation for two years, with and without anchorage and with and without traffic.

You will note from the report that we have submitted a formula for computing anchorage, and also some figures representing the resistance of a tie in ballast to movement, and have covered certain other phases in a general way.

The work remaining to be done consists of some additional tests of tie-in-ballast resistance against stone and gravel, also further study of continuous rail in track with conventional track fastenings, where there is high speed passenger service, and some additional study of the effect of one and two-way traffic on continuous rail. That should be completed during the coming summer and early fall, to the end that a final report can be presented at the annual meeting.

Vice-President Mottier: Thank you, Mr. Bartlett.

Chairman Caruthers: On Subject 3—Plans and specifications for track tools—no report will be presented this year, but considerable work has been done by the subcommittee. The work has not progressed to the point where it is ready for presentation. The work involves improvement of some of the track tools that are now shown in the Manual.

The next subject is No. 4—Plans for switches, frogs, crossings, etc.—and Mr. Bishop, the chairman of that subcommittee is not present, as he is still recuperating from a very severe accident. I will make the presentation of the report of that subcommittee for him. During the year the committee reviewed some of the plans and is making the following recommendations.

(Chairman Caruthers read the report on Assignment 4 and moved the adoption of the revisions. His motion was seconded, put to a vote and carried.)

Chairman Caruthers: We are indebted to the Standardization Committee of the Manganese Track Society which has collaborated with our committee in this work.

Considerable work has been done on some of the research projects, and Mr. Magee will make a report and give us some information on what progress has been made.

G. M. Magee (Association of American Railroads): In connection with the assignments on frogs and crossings, there are two research projects which have been assigned to us. One of these has to do with the guarding of the center frogs in the small angle crossings.

The present recommendation in the portfolio of Trackwork Plans shows that the minimum angle that can be used on tangent and up to 6 deg. curved main line track should be 9 deg. and 30 min. For sharper curvature, the minimum angle is increased up to about 16 deg. for an 18-deg. curve. A review of old records failed to reveal any method of calculation upon which the present recommendation could have been based. Accordingly, it was necessary to start from scratch and attempt to make what theoretical analysis of the problem we could.

Fig. 1 on page 328 illustrates the problem in a fairly simple manner. If the intersection angle of the crossing is as much as 17 deg. 26 min., the wing rail on one side is directly opposite the point of frog on the other rail, and there is no question but what the point will be adequately guarded. For smaller angular crossings, it is obvious that some length of the wheel flange can be depended upon for guarding. The question is to determine just how much this length will be.

In the report we have made an admittedly theoretical study of this, for both tangent track and curved track. The most important conclusions that were reached from the calculations indicated the very great benefit that would be derived from using a 1-in. raised wing rail, and also indicated that, without this wing rail, we were very close on the limit of avoiding derailments with our present recommendations.

This report is presented entirely as information and will be given further consideration by the Track committee and a decision reached as to whether any change shou'd be made in the present Portfolio of Trackwork Plans. If any of the members have any criticisms that they wish to submit, we will be pleased to have them. We have had one or two very constructive criticisms already on the report as presented.

Another project that we have in connection with efforts to prevent cracking in flangeways of solid manganese crossings is shown in Appendix 4–b. Briefly, the story on this work is about as follows: First we made measurements of the stresses in the flangeways of these crossings under passing trains and found that there was, due to the flexural action, a reversal of stress in the flangeways from a high compression to a tension approximately half as great. The obvious thing to do was to find means of lowering this stress range which, incidentally, appeared to be high enough to produce fatigue failures in manganese steel. Accordingly, several different designs of crossings were made and installed for service tests, and stress measurements were made on these different designs. These have been previously reported.

Upon the completion of these tests, these castings have been left in track for one-year intervals and their service performance observed. This year this part of the work will be concluded in May. The last one of the castings will complete a year of service.

In addition to that, as reported last year, a special type of T-beam frog support was designed and placed in the crossing of the Indiana Harbor Belt and the Chicago & Western Indiana here in Chicago. This crossing is being periodically observed. The purpose of the steel T-beam support is to relieve the casting of the flexural action, thus lowering the stresses in the casting.

Then, as a further line of investigation, since the flangeways of crossings are subject to so much corrosion and since we know that steels have their fatigue strength greatly lowered by corrosion, we have started some laboratory tests of the fatigue strength of manganese steel treated with various corrosion preventives, and also some subjected to

corroding agents. These tests also include specimens which have had surfaces shot peened. According to our present schedules, these laboratory tests will be completed this year and a final report made next year on that phase of the investigation.

Vice-President Mottier: Thank you, Mr. Magee.

Chairman Caruthers: The fifth subject was: Prevention of damage due to brine drippings. The committee has not made sufficient progress to present a report this year on that assignment.

The sixth subject, which is: Design of and stresses in tie plates, collaborating with Committees 3 and 4, will be presented by Mr. Macomb, chairman of the subcommittee.

J. de N. Macomb (Chicago): This report covers two subjects: (1) Revision of Specifications for Soft and Medium Steel Tie Plates and Specifications for Hot-Worked, High-Carbon Steel Tie Plates; (2) tie plate designs.

On page 356 are additional proposed changes in the soft and medium steel specifications. A correction should be made near the middle of the page by changing: "Delete the last two lines of paragraph 301" to read: "Delete the third line of paragraph 301."

The revision of the first specification consists in combining soft and medium steels and changing the title to low carbon steel. The changes are generally of a minor character, to clarify the specifications and bring them more closely in line with present practice.

On pages 356 and 357 are listed the proposed changes in the hot-worked, high-carbon steel specifications. The following correction should be made in them: Strike out the fifth and fourth lines from the bottom of page 356, beginning with "Paragraph 201, add fifth line as follows;" also beginning at the sixth line from the end of Assignment 6, at the middle of page 357, strike out four lines beginning with "Add new paragraph 403." These two items are already in the specifications.

As in the case of the soft and medium steel specification, the changes are generally of a minor character to clarify the specifications and bring them more closely in line with present practice.

I move the adoption of the revisions in the two tie plate specifications.

(The motion was seconded, put to a vote and carried.)

(Mr. Macomb read the three paragraphs under Simplification of Tie Plates and moved the substitution of these plans for those now appearing in the Manual.)

Vice-President Mottier: Mr. Macomb, may I raise a question? When these are published in the Manual, you will want this AISI changed to AREA?

Mr. Macomb: Yes, sir. If these are adopted by the AREA, they will be AREA plans. As published, they were AISI, because the AREA had not adopted them up to this time.

(The motion was seconded.)

S. R. Hursh (Pennsylvania): Why should not all 18 be adopted?

Mr. Macomb: Plans 4 to 13, inclusive, are in two groups, covering rails for 5½-in. and 6-in. rail base, which are the great majority of rails being produced at this time and for which tie plates are produced. There are, preceding those ten plans, three others, one for the 100-lb. RE rail section, which we did not have in the old plans, and two smaller single-shoulder designs for use with the older rail sections for which tie plates are occasionally required.

Now, the instructions to this committee have been, for a long time, to provide designs of tie plates for use with AREA rail sections, and some of the tie plates, numbered 14 to 18, are not for use in such rails. One of them is for use with the New York Central 127-lb. rail, which has a 6¼-in. base, and one for the Pennsylvania 155-lb. rail, which has a 6¾-in. base. That is one technical reason why the committee did not offer those plans for adoption and publication in the Manual, although the Association could perfectly well adopt them, if it cares to. The three other plans were of more special character.

All of the plans, but one, are canted 1 to 40. One of these plans is canted 1 to 20, to provide for the limited use of that cant. One has no cant; that is, a flat top. There are demands for a flat top tie plate but they are rather limited. One of them is a single-shoulder tie plate, 12½ in. long, which does not fall in the group of the two single shoulder tie plates at the beginning of the list.

Mr. Hursh: In reference to Mr. Macomb's explanation, it would seem that this joint committee functioned for the AREA as well as for the AISI, and it is true that some of the three sections are not universally used. But for some of the railroads that use those three sections, there are many more wanting tie plates, and in years to come there may be some other railroads that would like to use them. I think they should be adopted by the AREA as well as the first 13.

Mr. Macomb: I understand that another railroad is already considering the use of a 15½-in. tie plate for 155-lb. rail. So it is quite possible that in the future that might come into the list.

W. J. Burton (Missouri Pacific): I would like to ask Major Macomb if, in designing these plates, any consideration was given to the possibility of dimensioning the positions of the hold down holes, so that the same drilling of tie would fit several different plates?

Mr. Macomb: No, sir. We did that in some of the plans that are now in the Manual and, as far as I know, that practice has been very little used. It was considered rather unfortunate practice because, if you put the holes in proper position for one size of tie plate, they are not in very good position for another. So that was dropped in the present plans.

At any rate, your question, of course, is in regard to hold down holes. You could do it for hold down holes within limits. However, you could not do it for the line holes.

Mr. Burton: I notice the variations are slight, for instance, 2¼ in and 2⅜ in., which are such minor differences, that it looks as though this standardization might be feasible. It would simplify tie production so that the ties could be produced, as far as the hold down spikes are concerned, to a standard for use with several plates.

Mr. Macomb: To which two plans do you refer?

Mr. Burton: I notice on page 339 the dimension 2¼ in. as the distance from the rail out, and over on the next page it is 2⅜.

Mr. Macomb: I would like to call Mr. Burton's attention to the fact that the motion to adopt plans 1 to 13, incl., carries the proviso that they shall bear a note reading "Size and location of spike holes to be optional with a maximum of eight." Perhaps Mr. Burton is thinking a little beyond that and he would like to have the plans in the best possible shape, even if the punching is optional.

What I started to say was that the plans now in the Manual, where we attempted to work to a common tie boring would be, if you like, where a railroad has been using a certain tie plate for 5½-in. base and changed to another tie plate, presumably larger, for a 6-in. base. The great difficulty is to anticipate what many railroads are going to do. There is no use of trying to work it out for them, if they don't follow the plan that you have in view.

J. B. Akers (Southern): I notice here the suggestion that AISI plans be changed so that the size and location of spike holes will be optional. We want to know whether AISI accepts that as optional.

Mr. Macomb: I am sorry, I cannot speak for the AISI. I do not know what they would do.

Mr. Akers: It gets to be a rather serious thing with some of the railroads, our own in particular. It would cost us $40,000 or $50,000 if we adhere to our present location of spike holes. Naturally, we do not want to change that because of tie boring, and things of that kind. So, it is a matter of very great interest to some railroads, I am sure, whether the optional feature is only optional on our side.

Mr. Macomb: All that I can say in regard to the AISI is that the section of their manual, which they have published, in which these drawings are shown, has no such option shown. That is as far as I can go. I can tell you what has happened; I cannot tell you what might happen.

Mr. Akers: Have they had an opportunity to accept that as an option?

Mr. Macomb: Yes, I would say so. The Track committee of the AREA has held to that view. It was published in the bulletin a year ago, the one that I have referred to in this current discussion. I think the viewpoint of the railroads has been known to the manufacturers. For that reason, it was published.

Mr. Akers: Would there be a point in our showing an option in our Manual if it is of no effect?

Mr. Macomb: My thought about the AREA Manual is that it should set forth what the AREA believes to be the best engineering practice without regard to whether it is practically possible to secure the material. The Track committee has steadfastly held to this clause in regard to the permissive use of other punchings. As far as the Track committee is concerned, that is its report.

Mr. Akers: Right or wrong, many railroads have a different punching, for example, where the plan shows 3½-in. spacing for gage spikes our plan calls for 4 in. The recommendation of the committee says it is optional. We would like to have the benefit of the option but, in adopting it, if I vote for it, I would like to know that the option is something that will be effective.

Mr. Macomb: If you mean whether the manufacturers will accept an option of that kind, I cannot say. I can only speak for the AREA Track committee.

Mr. Akers: Then, why not postpone the adoption until we can clarify that point? I am asking for information.

Mr. Macomb: That, of course, is perfectly possible. The convention has that prerogative.

Mr. Akers: I am sure the membership understands there is quite a substantial extra demanded by the manufacturers for any change in the location of spike hole from the 3½ in. shown. That is what makes it so important.

F. S. Schwinn (Missouri Pacific): There is a possibility of the reverse of what Mr. Akers has said. Some large railroads must secure their plates from more than one mill. If they do specify the punching shown on these tie plates in the bulletin, one mill may be willing and offer to provide such punching, and another mill may refuse and offer a punching of its own.

Gentlemen, we have talked for years about the boring of ties but we cannot bore ties for several punchings.

Mr. Magee: I assume you gentlemen know that this subject has been very thoroughly discussed in meetings of Track committee and AISI representatives. It has been my understanding that the position of the manufacturers is this: They are willing to give us two punchings at the base price and, if we want any other punching than that, they have told us that they want an extra.

We, in these Track committee meetings, tried to find whether there were any two punchings for any one plate that would meet everybody's requirements. It seemed to be absolutely impossible to arrive at any such punching.

As a result of that, there seemed no alternative from the Track committee's standpoint but to say, that these punchings be shown as suggested punchings and other punchings to be optional. The question of price is something that is entirely out of the Track committee's hands.

Mr. Burton: I would like to supplement what has been said about the desirability of standard punching which takes into account the boring of the cross ties. Incidentally, as we all know, ties are an extremely important item of our purchases. It is highly desirable for a tie producer to anticipate demand before he has specific orders for ties and to produce ties and treat them, when the proper time arrives, so as to have a stock on hand and so that his production can be continuous throughout the year, and not in peaks when he gets orders, and for him to know that those ties which he has bored and treated can be sold, and that somebody will buy that particular pattern of boring.

If that punching can be standardized, at least as far as the hold down spikes are concerned—and I cannot see why it cannot be done—I think it would be of very considerable assistance in the production of cross ties and tend to reduce the cost of cross ties.

The tie plate is fundamentally a means of increasing the life of the expensive tie. If this is referred back to the committee for further investigation, I suggest that this point is a very good reason for doing so.

E. M. Hastings (Richmond, Fredericksburg & Potomac): I regret the necessity of having to speak again on this subject; I did last year, as many of you will recall. I am concerned as a matter of principle in this matter more than I am in the fact that it affects my own company. I stated to you last year that I felt that the matter of tie plate design should be one entirely within the province of the American Railway Engineering Association and that, when designs were brought out, they should be brought as AREA designs.

Now, I understand that that has been done, and the designs that are here presented for adoption, and three or four not for adoption but as information, are presented as AREA designs, with the proviso that the size and location of the spike holes can be optional, with a maximum of eight. What disturbs me is that even though this study

was going on intensively through the year of 1947 and down to the present time, last October, the Steel Products Manual was issued and was placed in the hands, I suppose, of all of the engineers and the purchasing officers of the various railroads, with letters from the several steel corporations stating that these designs for tie plates would be rolled but any departure therefrom would, of course, require an extra.

The thing that concerns me was the issuance of a manual by AISI prior to the adoption of the AREA plans. I need not say anything further on that. It was done.

Now, those of us who wanted some slight departure from the location and spacing of these holes have been advised that, "Yes, it would be provided but as an extra." I have forgotten what it was, 25 cents per ton per hole, wasn't it, Mr. Akers?

Mr. Akers: Something like that.

Mr. Hastings: That does not mean very much for my company but it means a lot to someone else.

Since the adoption of treated ties by the company which I represent, we have prebored all ties. As we are putting out ties for what we hope is more or less a finished track structure, that is, larger tie plates and a larger section of rail, we had hoped that this preboring would prove to be the proper boring for many years to come, and that throughout the life of the ties, at least, any renewals of plates would fit exactly the boring that we had. But if there is no option so far as the steel corporations are concerned, we are faced with the necessity of having to pay extra if we move a hole even as much as a sixteenth of an inch. This does not seem reasonable, and I think we are entitled to know whether or not, if these plans are adopted, with the proviso as to the size and location, the steel corporations will roll the plates.

I have no quarrel with the designs at all. I am heartily in favor of the standardization and simplification of designs, but I think somebody should be prepared to tell us whether the steel corporations will concede that the size and location of the holes is optional, or whether immediately the extra is to be added. It amounts to a great deal of money throughout this country; it will amount to more, if it involves the prebored ties and you attempt to drive spikes in holes that are off an eighth or quarter of an inch.

Therefore, I move as an amendment of the motion before us that the matter be referred back to the committee, with the request that this matter be cleared up and the plans brought in for adoption at a later date; in the meantime these plans to be used, as recommended, and be presented as information for those roads that desire to use them.

(The motion to amend was seconded.)

Mr. Macomb: This work on simplification and standardization of tie plates began with a conference between Mr. Tower, president of the American Iron and Steel Institute, and the late Mr. Pelley, then president of the Association of American Railroads, in April 1944. That is nearly four years ago.

Mr. Tower appointed a special committee to handle the work from the standpoint of the institute. Mr. Pelley assigned the work to the then existing Emergency Committee on Roadway and Track Problems of the Association of American Railroads. The institute committee assembled material, tabulated and studied it, and held periodic conferences with the railroad committee during the period of the war. With the termination of the war, the emergency committee on track and roadway problems went out of existence, after which the work, from the railroad standpoint, was turned over to the Track committee, which has carried on until the present.

Now, the manufacturers four years ago were forced to the conclusion that the great multiplicity of tie plate sections and tie plate punching designs had reached a point where it not only could not be extended, it could not be continued. Something had to be done. That was the cause of the conference between Mr. Tower and Mr. Pelley.

If the manufacturers had cared to at that time, if they thought it was the best thing to do, they could simply have said, "The standard plans in the AREA Manual are the base sections, and anything else will carry an extra." However, it was quite evident that, as most of those plans were then several years old, they did not adequately cover the railroad requirements, and the effort was made, by canvasses and studies of the designs for which the mills had equipment, and two canvasses of the railroads in regard to what they were using, to find out what design would best meet current requirements and practice.

After tabulations and studies, and after successive revisions, the plans which are now being offered by the Track committee have been arrived at. I just wonder how much better off the railroads would be if the manufacturers had used the plans now in the Manual as the basis instead of doing all the work that has been done.

Mr. Hastings: The point is that we have no objection whatsoever, I believe, generally to the plans as submitted; they are fine; the designs are fine. I think the committee that has been working for four years has done a splendid job toward the simplification. I agree that the plans that were in the Manual needed to be revised. The objection lies in the fact that, before the AREA has had an opportunity to adopt the plans for Manual material, there has already been issued an AISI bulletin, and the steel corporations have advised that any departure therefrom in the location of the holes will require an extra.

If the amendment, which I have offered, carries, it would then be the duty of the Track Committee. to ascertain whether some deviations can be made from these two punchings which are offered which, by the way, will require a good many mills to change their punching dies, or whether the principle of optional punching could be established.

A. A. Miller (Missouri Pacific): Suppose we consider further and the answer from the mills should be "No," then we should adopt, without fear of threats or outside pressures, as we have always and traditionally done, what this Association thinks best. I have no fears of penalties as I do not think any one or any company would even try to exact them. If further study, because other thoughts and information are made available, should be made and possible betterment result, then our Association can again say what it thinks is the best, or the best thing to do.

Vice-President Mottier: You and I will have a little dialogue to try to clarify something. It is your thought, I believe, as long as we keep in this provision which Major Macomb read a minute ago, on my suggestion, that the size and location of spike holes be optional, with a maximum of eight, that is about all we can do.

The argument as to price cannot be settled here on this floor today. That is one point.

Mr. Miller: That is correct.

Vice-President Mottier: There is another point. Mr. Burton's comment about standardization of holes is excellent, but I would not know at this moment what that standardization should be that would fit the Missouri Pacific, the Southern, the R. F. & P., and the Pennsylvania.

Mr. Miller: I think the word "optional" covers my thought. This Association cannot, and should not be permitted to, compel any railroad to do anything. With time. tests, experiments and seasoned experience, together with mature judgment, railroads generally have followed and approved the recommended practices of the Association; that definitely is so with respect to the Missouri Pacific Lines.

Vice-President Mottier: Pardon the chairman for making a few remarks, because we have gone up the hill and down the hill on our railroad in this discussion, and up the hill and down the hill on the Board.

Let me make just one or two observations, with a view to leading up to a vote. The report here states, and as Major Macomb has explained, that the adoption of these (let's confine it) 13 sections was primarily for the purpose of simplification. The joint committee made a study and arrived at the conclusion that this group here is about the smallest number that would have a wide range of use. The committee did not necessarily try to find out what was the best design.

It is my further point that, in our research program we are trying to develop a design of tie plate that is theoretically sound, but that will be a matter of two or three years anyway, before that can be done. In the meantime, in the interest of this simplification and after considerable work, the committee developed these 13 sections which cover the AREA rail sections, with this notation.

Frankly, not as an arbitrator, it would seem to me that the thing for us to do is to support the recommendation of the committee in this. I do not know what you would gain in this argument with the manufacturers about the extra for the punchings, by any action that we would take here today. That is not clear to me.

It might be that it would show our resentment and our criticism of the procedure of the manufacturers, which might give us some consolation. But, beyond that, I do not see what we would gain by it.

Gentlemen, you have a motion, and you have an amendment to that motion. The motion is that we adopt, for printing in the Manual, plans 1 to 13. The amendment would refer the plans back to the committee for further consideration.

We vote on the amendment first, which is that the matter be referred back to the committee. All those who are in favor of the amendment please rise. Those who do not wish the amendment to prevail will please rise. The motion is lost. We now vote on the motion.

(Mr. Macomb's motion was then put to a vote and carried.)

W. P. Wiltsee (Norfolk & Western): Before you leave the tie plate section, I would like to ask the committee if it considered any larger tie plates than those recommended. I am a great believer in the work of this Association, and I follow it in every way I can, but our railroad, the Norfolk & Western, some five or six years ago adopted an 8 by 18 tie plate. We use it on curves of 4 deg. and over. There is no such tie plate in the Manual for recommended practice. I could not get our people to go back to a 15-in. tie plate. They are sold on the 18-in. tie plate. It has proved very satisfactory and has reduced the tie damage.

Mr. Macomb: There are five sections each for rails with a 5½-in. base and with a 6-in. base. Of the sections for the 5½-in. base one, the 14-in. plate, to my knowledge has never been used. So we have anticipated developments in that direction; in the 6-in. base we have not. The 14¾ is the largest section.

I might say that, since the work done by the committee went to publication, the question has come up about a tie plate for use on curves, and a couple of suggested designs have been put out which are 15 and 16 in. long. So, in a way, the committee is anticipating that.

Wherever a railroad has a condition such as Mr. Wiltsee speaks of, where it is desirable to extend this series of designs, if they would take that up with the chairman of the Track committee, if the committee so desires, it will add the design, and they will seek a conference with the manufacturers. The manufacturers have indicated a willingness to consider such designs when they come to them through the Association. So, the channels are all open. If there is a desire and necessity for tie plates larger than those already in the Manual, it is a perfectly simple matter to get them.

I have one more thing to say, and that is tie plate sections 14 to 18, inclusive, are offered as information.

Vice-President Mottier: They will be so received.

Chairman Caruthers: In behalf of the committee, I would like to assure the convention that a great deal of time has been spent on this subject both in the subcommittee and in the entire Track committee. The situation is such that the committee has presented what was finally decided as the best results that could be obtained.

Further, from Mr. Wiltsee's standpoint, the committee has under consideration larger tie plates, modified, particularly at the present time, to take care of curvature. So, the door is open, as the Major has said, and studies will continue. The steel companies have condescended to consider such designs as we might later on feel in position to recommend.

To continue with our report, Subject 7—Hold-down fastenings for tie plates—will be presented by Mr. Blowers, chairman of the subcommittee.

(Blair Blowers, Erie, read the first two paragraphs, of the report on Assignment 7.)

Mr. Blowers: Through the kindness of Mr. L. L. Adams, assistant chief engineer of the L. & N. Railroad, a test installation was made on the northbound main track near London, Ky. The AAR furnished most of the tie plates and the hold-down fasteners. The L. & N. furnished all labor and materials, including 2800 new ties, and did a very fine job.

The report of the various types of fasteners which were applied is shown on pages 358 to 361, incl. The construction work was done in August and September of last year. We took the initial readings in November, which consisted of a record of what little wear there was on ties at that time, track gage, curvature. Of course, there will not be much penetration for several years. We will take the readings every year and will report as it works out.

All the construction work was performed under the direct supervision of H. E. Durham, track engineer, AAR, and under the general direction of Mr. Magee, research engineer.

In connection with tests on the Illinois Central that I mentioned, we took additional readings this year, but there was very little additional mechanical wear, and we will not make any report. We will continue on that, also, and submit a report later.

Vice-President Mottier: Thank you, Mr. Blowers.

Chairman Caruthers: No report will be made this year in connection with Assignment 8—Effect of lubrication in preventing frozen rail joints. Work is progressing, however, in the committee and at a later date further information will be offered.

On Assignment 9—Recommendations on number and placing of anti-creepers for various conditions—Mr. Martin, the chairman, is not with us today. Mr. Magee will make the report for that subcommittee.

Mr. Magee: The report this year is a final report on the conclusion of the service tests of different methods of rail anchorage started some four years ago. These tests were made on three different railroads. The one test was on the Milwaukee Railroad near Mauston, Wis., a double-track line, carrying traffic in one direction; 131-lb. RE rail and gravel ballast. The second test was on the Illinois Central near Kankakee, Ill., a three-track main line carrying traffic in one direction on test track; 112-lb. rail and crushed stone ballast. The third test was on the Milwaukee Railroad near Kansasville, Wis., single track, carrying traffic in both directions, 112-lb. rail and gravel ballast.

During the four years periodic measurements have been made of the rail creepage, tie slewing and tie movement. It was felt, from the results obtained so far, that final conclusions can be drawn this year. That has been done. On page 370 of the report the following recommendations are made for revision of the Manual. Mr. President, it is the recommendation of the committee, and I so move, that the matter on page 5–18 of the Manual reading as follows:

"ANTI-CREEPERS

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"The use of anti-creepers to prevent longitudinal movement of rail in track is recommended."
be eliminated, and, in place, thereof, the material headed

"RAIL CREEPAGE—NUMBER AND POSITION OF RAIL ANCHORS"
be substituted.

(The motion was seconded.)

R. B. Jones (Canadian Pacific): I take it that this report is not in favor of group anchoring of rail. On the Canadian Pacific, about the time that the Track committee started its experiments of rail anchors, we also did. We have practically solved our difficulties by group anchoring. Our conclusions are exactly contrary to those expressed by the committee.

I see no reason why we should be hurried into getting this thing into the Manual. I think we all have a great deal to learn about rail anchors. I do not believe to distribute anchors along the rail is sound. I think, to make it work successfully, you must first establish the expansion. If you want to hold a rail against expansion, I don't see how you can assume that each rail anchor is equally effective if they are spread along the rail.

Accordingly, I would move an amendment to the motion indicating that this report be accepted as information, and give us all a little more time to study it.

Mr. Magee: I would like to ask, first, by group anchoring do you mean placing your anchors in a group on one rail and the other rail directly opposite, or only on one rail and not on the same ties on the opposite rail.

Mr. Jones: Obviously, this would not be the place to get into an extended argument with the committee. We have found, if ties skew when an anchor is applied on one rail only, that that is an indication that there is not sufficient anchoring and not a condemnation of the method. It is our belief that by applying anchors by boxing the ties at one rail, with none on the other end of the same ties, we increase our total anchorage.

Mr. Magee: I suppose you know that in all three of these tests that type of anchorage was included, using just as many anchors per panel as we applied with the other methods. But with that method we found much more skewing of the ties, in fact very objectionable tie skewing, which tended to kick the joints out of line and tighten up the gage.

It is the intention of the report to recommend against the group anchoring. That is the definite intention.

Mr. Jones: It is my information that we are not alone in obtaining very successful results with group anchorage. It seems to me it is rushing it a bit to tell us that we must put anchors on this way and to tell us how many anchors we must put on. We found we can hold track with a lesser number of anchors than you recommend.

Mr. Magee: I am sure it is not the intention of the committee to tell you how you have got to put on your anchors. These are recommended practices which have been very carefully gone into. We are offering a recommendation. Certainly, if you prefer the anchor method, it is your privilege to use it.

Mr. Jones: I dislike to take a contrary view. It is my view that the information submitted in the report has not been correctly outlined.

(The motion to amend was seconded.)

H. S. Loeffler (Great Northern): I would like to speak from our experience. Some years ago we started to group the anchors at the quarter points, and the last few years we have discontinued that practice. My theory of the matter is that the grouping of the anchors at the quarter point was likely to result in a rough track. In other words, anchorage should be uniformly distributed throughout the length of the rail, which agrees with the committee report. Fundamentally, if you are going to distribute a load to the ground, whether it is track anchorage or the load from a structure, the scientific thing to do is to distribute that load, not concentrate it at a given location.

I heartily agree with the report as made by the committee.

Vice-President Mottier: I would like to ask Mr. Chumley to make some comment because of the experience that we have had on test track.

C. M. Chumley (Illinois Central): Our experience has been that in anchoring one rail, that is, to put anchors on one end of the tie and no anchors on the other, the tie will be skewed until the gage is tightened and the line is disturbed. That has been the experience on our own railroad, and on another road that I have observed, I found the same condition. I am in accord with what the committee has worked out.

Vice-President Mottier: Thank you, Mr. Chumley.

(The motion to amend was not sustained. Mr. Magee's motion was then put to a vote and carried.)

Chairman Caruthers: That concludes the report of the Track Committee for this year.

Vice-President Mottier: Mr. Caruthers, I have heard a lot of criticism about the convention procedure being bad—that we never have any discussion from the floor of the convention. We have had quite a bit this afternoon. You are excused with the thanks of the Association. (Applause)

Discussion on Impact and Bridge Stresses

(For Report, see pp. 276–284.)

(President Chinn presiding)

Chairman A. B. Chapman (Chicago, Milwaukee, St. Paul & Pacific): The report of Committee 30—Impact and Bridge Stresses—covers 11 assignments, and we are reporting on all of them except assignments 5 and 6. The reports on assignments 1, 2, 3, 4, 8 and 11 are presented as information, principally to show that work is progressing on these assignments, while detail reports are presented on assignments 7, 9 and 10.

Considerable work has been done on the girder spans, and the research staff of the AAR will continue the testing of spans of this type this summer. Your committee originally selected 30 girder spans for testing, their lengths varying from 40 to 140 ft., both open and ballasted decks, and two-thirds of these spans have already been tested. A total of 2000 runs, of which 600 were with diesel and electric locomotives and 1400 with steam locomotives, have been secured to date during the testing of girder spans. It appears from these tests as shown in the diagrams presented in the report of the Iron and Steel Structure committee, that the impact in the shorter girder spans is not as great as we had originally thought.

The last work done on Assignment 6—Analysis of additional data from impact tests—was the analysis of the data secured by the Pennsylvania Railroad brings tests at Elkton, Pa., and presented as information in the 1944 AREA Proceedings, Vol. 45, 1944, page 47.

One of the important impact effects in a truss span is caused by the periodic disturbing force resulting from the unbalanced weights in the driving wheels of the steam locomotives. The Impact committee originally felt that if these vibrations could be induced artificially with a known disturbing force and the strains and deflections measured so that the damping factors could be determined, the tests on truss spans could be greatly simplified. Accordingly, in cooperation with Ohio State University, a mechanical oscillator was built, extensive tests were made on a truss bridge at Springfield, Ohio, and the results of these tests are reported on page 747.

The results of these tests indicated that the stresses in the member of a truss are not magnified in the same ratio as the deflections. The stresses in some members of this test span were magnified twice as much as the center deflection, while the stresses in others were magnified only about half as much. This we interpret to mean that the deflections of a truss span cannot be used as a measure of the amount of impact in the individual members.

In general, it was found that the recorded live load stress in the lower chord of the through span was lower than the calculated, while the recorded stress in the top chord was greater than the calculated. This variation is apparently due to the fact that the stringers act as part of the tension flange; thus reducing the lower chord stress. With the stringers acting as part of the lower chord, the effective depth of the spans was decreased, thus increasing the upper chord stresses.

The committee now feels that, in the future, the impact values in truss members should be determined by measuring the strains in the various truss members produced by diesel and steam locomotives, and recommends that Assignment 7 be discontinued.

During the past few years the research staff of the AAR has been asked by several of the individual railroads to conduct tests on their truss bridges to determine the carrying capacity of these structures. Some of these bridges have been in slow speed territory while others have been in territory where speeds of 40 to 50 mph. could be attained. We feel that the data obtained from these tests will be of value to the railroad bridge engineers and we are presenting a report of tests made on the Toledo Terminal Railroad on page 677.

The tests were made on a 142-ft. deck span and a 250-ft. total length through draw span at the request and expense of the railroad for the purpose of determining the carrying capacity or rating of the steel superstructure.

The analysis of the data secured on these two truss spans under the passage of 178 test trains at various speeds ranging from 10 mph. up to 43 mph. indicates the following:

1. There was considerable variation between the calculated and recorded static stresses in the chord members, and we feel this is due to the action of the stringers in taking direct stress. There was fair agreement between the actual and calculated static stresses in the web members.

2. There was good agreement between the recorded and calculated static stress in the web and chord members of the 250-ft. draw span, indicating that the static stresses can be reliably calculated for this type of structure.

3. The impacts in the various members of the 142-ft. span were determined, and it is evident that the impact is not the same in each member of the truss, which confirms the results of the oscillator tests. The impacts in both the chord and web members were greater than the present AREA design allowance. However, the impacts in the web members are greater than those in the chord members.

4. It was found that the magnitude of the impacts in the 250-ft. draw span were about the same as those recorded in the 142-ft. span.

5. The simultaneous stresses were measured at the four corners of each member and considerable variation was found between the corner stresses. The variation in stress between the corners is called secondary or bending stresses and was found to be as large as the impact stresses in some members.

The report on Assignment 10—Distribution of live load in transverse floors and longitudinal stringers—can be found on page 279. The data for the report were obtained during the testing of a 100-ft. through girder span having a ballasted deck. The floor beams carrying the ballasted deck consisted of wide flange beams spaced at 18½ in. centers transverse to the center of the track.

The simultaneous static stresses in 24 consecutive floor beams were obtained for any position of the locomotive as well as the maximum stress in each floor beam as the locomotive passed over the beams.

The analysis of the data indicated the following:

1. The load on the floor beams from the locomotive axle loads is not uniformly distributed to the beams. It appears that the stress in every fifth or sixth floor beam is increased by center-bound or tight ties.

2. The average stress in floor beams can be calculated with a fair degree of accuracy by using the present AREA design specification recommendation for the distribution of the locomotive axle loads.

The research staff of the AAR conducted tests on five bridges for the individual railroad during the past year, and we are advised that after an analysis of the data was completed, authority was secured for the replacement of two of the bridges which showed inadequate strength.

The tests on another bridge indicated that only certain members were over-stressed, and an expenditure of $10,000 for strengthening was sufficient to keep the bridge in operation instead of requiring a replacement estimated at $150,000.

Committee 30 for the coming year plans to divide its work among subcommittees, appointing a subcommittee chairman in each case who is a member of one of the other AREA committees which are interested in the particular project; that is, Committee 7 will cooperate with the AAR research staff in the method of obtaining information on impact in wood bridges. Likewise, Committee 8—Masonry—will deal with concrete subjects, and Committee 15 with iron and steel subjects. It is hoped by this method that the committee will keep in closer touch with the desires of the various committees and obtain data which can be used to better advantage.

The committee will welcome any suggestion anyone has to offer.

Mr. President, that completes the report.

President Chinn: Mr. Chapman, your committee is carrying out a most valuable piece of work, and we are indebted to you for this review of the progress that has been made in the important investigations being conducted under your supervision.

Your committee is now excused with the thanks of the Association. (Applause)

Discussion on Masonry

(For Report, see pp. 243–268.)

(President Mottier presiding.)

Chairman F. R. Smith (Union): Committee 8 has been assigned nine subjects for study. This year we are reporting on specific assignments under the following five: Revision of manual; Design, Foundations, Earth pressures, and Tunnels.

During the past year your committee had three outstanding meetings with an average attendance of 65 percent. I think that is a marvelous record, and I want to congratulate our committee for its exceptional attitude in maintaining an active interest in our work. We also want to thank the employing companies for permitting their men to attend these meetings and for recognizing the importance of our work as related to the Association.

Some reports that have been presented have controversial issues or hot spots on which the committee consumes considerable time in discussion at its meetings. As reports are presented, we request that you feel free to ask questions of subcommittee chairmen regarding these thought-provoking points. By so questioning, we might be able to improve our reports before offering them next year for adoption and publication in the Manual. You also might receive some assistance for your problems at home because of the intensive study given these subjects by the respective subcommittees.

If your questions cannot be answered here, we shall be pleased to endeavor to find the answer and reply by correspondence.

The report on Assignment 1 will be presented by Mr. Johnson, who has done tremendous work on this subject. Your undivided attention is requested because what he has to propose pertains not only to Chapter 8, but could be applied to the entire Manual.

A. C. Johnson (Elgin, Joliet & Eastern): This is a brief progress report on revision of Manual.

For some time Committee 8 has felt the need of a complete revision of our chapter as it is now printed in the Manual, purely from a mechanical standpoint. As our chapter is now printed, a great deal of confusion exists in the mechanical structure, even going so far as to finding material and similar subjects scattered throughout the chapter. This is not the fault of any individual or of any particular committee. It is more the natural sequence of the normal working procedure of many AREA committees. There are two major contributing causes. One is the continual changing of personnel of the committees, and the second is the tremendous cost of reprinting complete chapters for minor revisions.

Our chairman, Mr. Smith, asked me to try to do something about the elimination of these two causes. Our committee therefore started with the thought of setting up a skeleton outline for our chapter which could be followed in the future, thereby assuring logical order of placement of material in our chapter. Secondly, of course, was the idea of some system whereby minor changes or revisions would not cost too much in the way of reprinting.

We approached our subject in this manner: We felt that the chapter in its entirety was too large to be considered as a single unit. We felt that the chapter should be broken down into sections, and these sections be made distinct entities, so that changes made in a section would not necessarily require any reprinting of the balance of the chapter.

We also felt the sections should be set up in chronological order of use. By this I mean the use from the designer's standpoint and then from the structural man. We therefore started out with our sections in that manner. But, having set up the form for our section, we felt it necessary to break the section down into three parts.

We would have the section heading, and under that we would break down into articles, parts and paragraphs. Keeping in mind the thought of minimizing the cost of reprinting, we elected to use section designations by Roman numerals, articles by capital letters, parts by the Arabic numerals, and then the smallest paragraph by a lower case letter. We had in mind the reference to particular parts of the chapter in other portions. In this set-up we would be able then to make simple references and not go into a great deal of reprinting.

Attacking the second part of our problem, minimizing reprinting, we are at present handicapped by the present method of page numbering, figure numbering and table numbering. Our subcommittee at once realized we were stepping out of bound; it does not fall within our assignment, but to fulfill our ambitions and, therefore, to fulfill the full benefits of this lowering cost of reprinting, we are making as a suggestion only, to the Board, to keep in mind for long-time planning a complete revision of the numbering system of our entire Manual.

What we have in mind, of course, is the sequence numbering system whereby each chapter would continue, as at present, with its chapter number. This, in turn, would be followed by a dash and a number indicating the section. This, in turn, would be followed by the page number of the section. As an example, let me take the first section in our own chapter. The first page number would then be 8–1–1; second in that same section would be 8–1–2. We would go to the second section and we would have 8–2–1, and so on.

The reason for this is self-explanatory. In that way you would have each section of each chapter having its own page numbering and not changing any pages in other chapters or sections of the Manual.

We would also like to go a step further and have all tables, figures and so forth, numbered pertaining to the section in which they occur.

As Mr. Smith said, this is only our idea of a Manual revision, and we welcome any criticism from the members.

President Mottier: Thank you, Mr. Smith. I assure you and your committee that our Board, particularly the Committees on Manual and Publications, will be very glad to work as cooperatively with you as we possibly can.

Chairman Smith: The report on Assignment 3 will be presented by Mr. Ornburn.

B. J. Ornburn (Chicago, Milwaukee, St. Paul & Pacific): We wish to submit our reports on the Specifications for the Design of Concrete Transmission Poles, Specifications for Crib Walls, and Specifications for Reinforced Concrete Culvert Pipe for your consideration.

The proposed Specifications for the Design of Concrete Transmission Poles were presented last year and appear in the Proceedings, Vol. 48, 1947, page 449. It was felt that the specifications now printed in our Manual were inadequate to cover this subject, especially in regard to ice loads and the setting of poles. We now specify an ice coating ½ in. thick as the ice load on the conductor, regardless of the location. Your committee, after giving consideration to this matter, proposes that we use the ice loads as now adopted and stipulated in the National Electrical Safety Code. A zoning diagram for the proposed ice loads is shown on page 450.

Our present specifications provide only for setting concrete transmission poles in a concrete foundation except under special soil conditions, and that the poles be set not less than 6 ft. below the top of the ground. We have provided in the proposed specifications for the setting of these concrete transmission poles directly in the earth and made the depth of the setting of the pole dependent upon the permissible passive resistance of the soil in which they are to be placed. Formulas for determining the conductor pulls, the soil passive resistance and the soil pressure at the bottom and at the axis about which the pole will rotate are now included in the proposed specifications.

When your committee submitted these specifications it made an urgent request for critical review, comments and criticisms so that it might constructively amend the specifications before offering them for adoption. However, no criticisms have yet been received.

In reviewing these specifications for making this report, it was noted that there are a few omissions and errors:

In paragraph 9 (e) regarding design of pole, it states that the axis of the moment shall be taken at the top of the ground. This is in error; the axis of the moment should be taken at a distance one-half a below the top of the ground.

Our present specifications provide for a wind pressure of 15-lb. per sq. ft. on the projected area of the wires, cables and hangers and 8-lb. per sq. ft. on ice coated wires, cables and hangers. It was agreed that the wind pressures should be changed to conform to those given in the National Electrical Safety Code, but, unfortunately, they were omitted when sent for printing.

In the diagram shown in paragraph 11 (a) and the nomenclature following, the small letter h is used to denote distance from top of ground to point of application of the conductor load in feet. Later in the same paragraph the small h is used in the formula for determining the permissible passive resistance of the soil. Here small h denotes the distance in feet below the ground surface. The latter is in error and should be revised.

Your committee recommends that these Specifications for the Design of Concrete Transmission Poles be printed in the Manual with revisions as required to correct these omissions and errors. I move the adoption of this report and its printing in the Manual, as revised.

(The motion was seconded, put to a vote and carried.)

Mr. Ornburn: Now on the Specifications for Reinforced Concrete Culvert Pipe: Since 1944 it has been the feeling of many railroad engineers that stronger reinforced concrete culvert pipe than that now being used should be provided under railroad tracks for present railroad loads. This year your committee drafted the specifications as shown on pages 251, 252 and 253 of its report to cover such reinforced concrete culvert pipe. It is recommended therein that the proposed pipe shell thicknesses shall be equal to the present shell thicknesses of reinforced concrete culvert pipe now made in accordance with ASTM Specifications C 76–41, Table II.

Theoretically, the proposed pipe is based on a design using a uniform load of 2500 lb. per sq. ft. on the projected horizontal diameter without lateral restraint. No tests have yet been made to determine whether or not the proposed reinforced concrete pipe would actually stand up under the test requirements as proposed in Table III.

This proposed pipe is designed on the basis of an ultimate concrete strength of 4500 psi. Table III provides for using circular pipe with single and double lines of circular reinforcement, circular pipe with elliptical reinforcement and elliptical pipe with circular reinforcement. There have been some criticisms of specifying the circular pipe with elliptical reinforcing. Your committee found that some railroads use a considerable quantity of this type of pipe, and it was felt that for that reason we should include all three types of pipe.

Your committee has received some other very constructive criticism on this specification and will continue its study further before presenting the specification for adoption. It has been submitted entirely for information, and we will appreciate your criticisms from the floor and welcome your letters regarding this matter.

I will now ask Mr. Dayett to give us the report on crib walls. He has spent so much time on this, he is so much better acquainted with it than I, that I feel he can present it to you so much better than I can.

G. H. Dayett (Baltimore & Ohio): Committee 8 was requested to prepare a specification for crib walls. The subcommittee has prepared these specifications. They include specifications for concrete cribbing, metal cribbing and timber cribbing. They have been considered by the committee, and I do not believe it is necessary at this time to read those pages.

However, I would mention that the committee considered that crib walls are a type of retaining wall, and these specifications require that the crib wall and the individual members be so constructed that the design would satisfy the same external loads as are considered acting on monolithic retaining walls. These specifications are very specific but they are short, and we tried to make them definitely to the point for the use of the designing engineer. They are presented as information at this time. If there are any questions, I will be glad to answer them.

President Mottier: Any questions or comments?

Thank you, Mr. Dayett.

Chairman Smith: The report on Assignment 4—Foundations—will be presented by Mr. Nearing.

M. Nearing (New York Central): This subcommittee was assigned, among other things, the revision of the specifications for pile foundations in collaboration with other committees.

We thought that the best way to get proper collaboration was by printing our thoughts and expecting criticisms from the interested committees and possibly meeting with them to iron out our difficulties. I am quite sure that everyone who is interested has read the specifications as printed, and I will not read them but will review very briefly the changes that were made in the present specifications.

The introductory articles and the article on design were not changed any, they are printed as they now stand.

The article on allowable loads is quite new. As it goes into the subject of soil mechanics, it probably involves further discussion, and we expect it will be somewhat revised before being presented for publication.

The article on testing of piles also is quite new and goes into considerable detail on the method of running pile tests. The articles on individual piles, the first being on precast concrete piles, are substantially what is now in the Manual.

On the subject of cast-in-place concrete piles, we have made considerable revisions in the present specifications. The reference to cast-in-place concrete piles with the shells removed has been deleted because the committee thought that such piles were satisfactory only under certain driving conditions, and that they are not, strictly speaking, piles. They may be considered later under some such subject as soil consolidation or special foundations. Also, we considered such piles could not be driven in conformity with the specifications which will fit the driving of immediately adjacent piles, after a pile has been filled with concrete.

In the interest of uniformity, all the specifications covering steel piles of all shapes, rolled shapes and shells and piles, have been somewhat revised so as to allow in the shell piles, the cast-in-place piles using shells, the shells to be of sufficient thickness to be considered in design as taking some stress. Also, the provision now in the pipe pile specifications, calling for the deduction of a certain amount of steel from the outside of the pile to take care of erosion or damage during driving, is applied to all steel piles.

The two driving articles now on pages 89 and 122 of the Manual have been combined into one article. You will notice that we have not yet accepted any pile-driving formula, although we know that formulas are used on smaller jobs. We recommend the use of soil investigation and test piles in determining the allowable load on piles.

This report is offered as information with the understanding that we will revise it during the coming summer and offer it for publication in the Manual next fall. If there are any comments or questions about it, we will be glad to hear them, and we hope to get comments by letter, if not from the floor.

President Mottier: Anyone want to make a comment?

Thank you, Mr. Nearing.

Chairman Smith: We have no formal report to make on Assignment 5—Earth pressures—but Dr. Peck of the University of Illinois, who is chairman of the subcommittee, will now talk to us regarding the preliminary conclusions related to retaining wall failures.

(Dr. Peck presented his report which appears at the end of this discussion.)

Chairman Smith: Report on Assignment 6—Tunnels—will be given by Mr. Porter, our vice-chairman.

C. B. Porter (Chesapeake & Ohio): Your committee has previously prepared specifications for lining railway tunnels with concrete, metal, shortcrete and brick. Many railroads continue to use timber linings for tunnels, not only on branch lines but also for main line tunnels.

A study of methods used for such linings by railroads indicates a general similarity. However, there is somewhat of a variation in certain construction details.

Committee 8 was given the assignment to prepare a specification for lining railway tunnels with timber. This specification, which is tentative, is printed as information on page 264, and no doubt all of you who are interested have read it.

In the preparation of these specifications your committee has attempted to present what we consider good practice. We wish to emphasize, however, that these specifications cover lining of new tunnels through ordinary formations which involve no special features. Your committee recognizes the necessity of permitting the engineer considerable latitude in the selection of set spacing and certain other details as the tunnel excavation advances.

We realize even through ordinary formations, conditions may change from day to day as the tunnel excavation advances Your committee is of the opinion that only fire retardant timber treatment should be used in tunnels. We have attempted to present in paragraph 4, specifications for fire retardant treatment which we consider to be probably the best that we know of at this time. However, I am informed that Committee 17—Wood Preservation—is now hard at work on the specification for fire retardant treatment for tunnel liners, and we hope that this specification will be in such shape that it can be included in our specification before it is presented.

We wish to add a sentence after the second sentence in paragraph 17, under Packing, as follows:

"When treated timber lining is used, packing of timber shall be treated as outlined in paragraph 4."

Your committee feels that, if we use treated timber for any part of the liner, we should use it throughout. Also, in paragraph 18, the second line, after the word "Paragraph" the number "203" should be changed to "7".

Your committee earnestly invites your comments and criticism of these specifications, which will be a new section in Chapter 8, that they might be constructively amended prior to presenting them for adoption at the next annual convention.

President Mottier: Thank you, Mr. Porter.

Anyone wish to make any comment?

Chairman Smith: The reports of Committee 8—Masonry—are now concluded. I do want to take this opportunity to extend my sincere gratitude, thanks and appreciation to each member of this fine committee for his conscientious cooperation, his time and his trouble in progressing our work during the past year, by faithfully coming out to meetings and by promptly handling his correspondence.

President Mottier: We all wish to extend our thanks to the Committee on Masonry for its excellent report.

The committee is excused. (Applause)

A Study of Retaining Wall Failures

By R. B. Peck

Research Professor of Soil Mechanics, University of Illinois, Urbana,

Under the auspices of your Association, questionnaires were sent to the chief engineers of all the American railways requesting information about retaining walls or abutments that had failed or that had experienced progressive movement to an undesirable extent.

The questionnaire brought forth information about a large number of retaining walls and abutements. The failures and movements have been analyzed with respect to their probable causes. It has been found that, with very few exceptions, the difficulties were due to misjudgment of foundation conditions rather than to incorrect assumptions regarding the backfill pressure.

In 1945, the Committee on Masonry appointed a subcommittee on earth pressures against masonry structures. The principal assignment of this subcommittee is to study and revise the current specifications of the Association with respect to retaining walls and abutments.

As one of the initial steps in this study, a questionnaire was sent to all of the principal railroads of the United States and Canada to obtain information about retaining walls and abutements that had performed in an unsatisfactory manner. In particular, information was requested concerning retaining walls that had failed completely or that had experienced movements of such magnitude that their function had been impaired. Data were not requested, however, about failure of abutments by scour.

The chief engineers of 77 railroads were invited to contribute information. Of this number, 37 or 48 percent did not reply. An additional 24 or 31 percent reported that no

Fig. 1.—Locations of Examples Reported.

difficulties of any consequence had come to their attention or that failures had occurred only in very old walls designed according to rules of thumb now considered obsolete. The remaining 16 or 21 percent reported that the behavior of at least some walls and abutments had been unsatisfactory enough to cause concern. These 16 submitted information about 44 walls and abutments that were considered unsuccessful. The location of these structures is shown in Fig. 1.

Inasmuch as almost 80 percent of the individuals to whom questionnaires were sent either reported no difficulties or did not reply, it would appear to be a reasonable

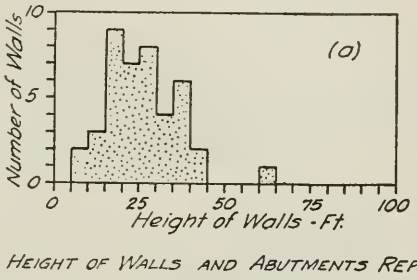


Fig. 2.—Reported Movement of Walls and Abutments.

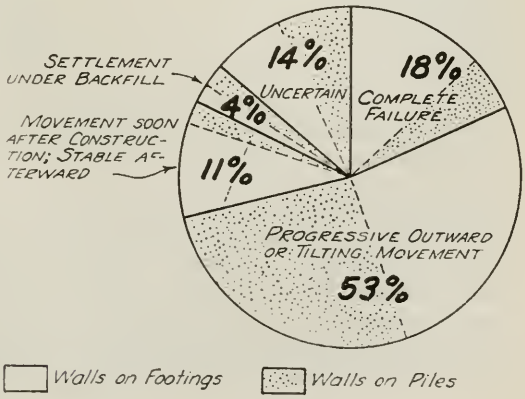


Fig. 3.—Types of Unsatisfactory Behavior.

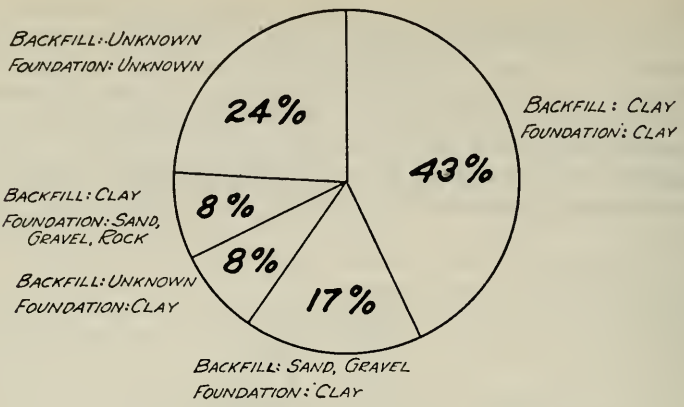


Fig. 4.—Backfill and Foundation Materials; Walls Subject to Progressive Outward Movement.

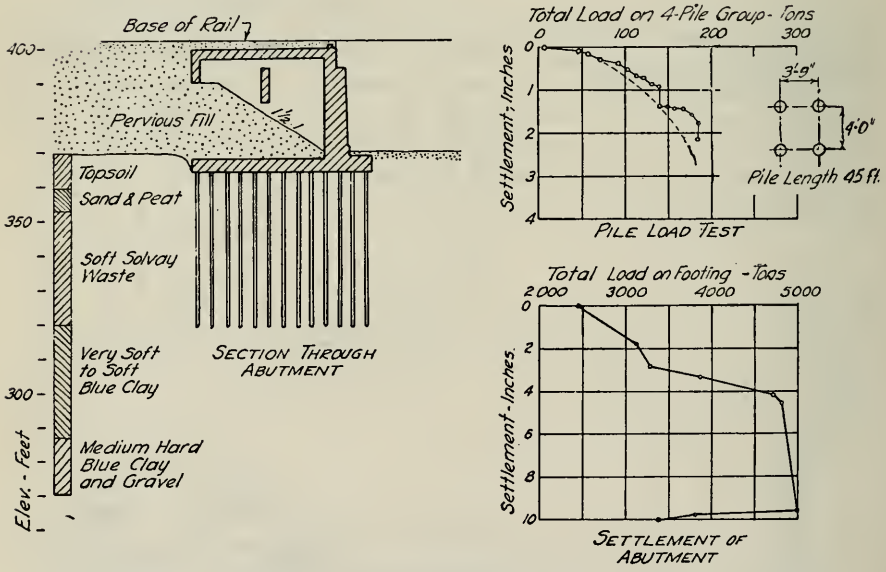


Fig. 5.—Failure of Abutment Due to Exceeding Bearing Capacity of Subsoil.

conclusion that the great majority of retaining walls and abutments can be considered successful and that as a rule the present methods of design are at least adequate and possibly conservative. Nevertheless, a sufficient number of failures or examples of excessive movement were reported to indicate that walls designed according to the customary procedures are not necessarily stable or static.

The unsatisfactory walls and abutments are classified in Fig. 2a according to their height. In Fig. 2b they are classified in accordance with the magnitude of the move-

ment they experienced. The majority experienced forward movements of 6 to 12 in. This is probably an indication that movements less than 6 in. are commonly not a matter of concern and it suggests that movements smaller than about 3 in. are usually considered quite normal and satisfactory.

In Fig. 3, the walls are classified in accordance with the type of movement that they experienced. It may be observed that about 18 percent failed completely. That is, they either overturned, broke structurally, or were considered in such imminent danger of collapse that they had to be strengthened or removed and replaced. Over half of the walls experienced a progressive outward or tilting movement.

Piles Did Not Prevent Movement

Fig. 3 also indicates that almost half of the unsatisfactory walls were supported on piles. This fact suggests that there was general recognition of unsatisfactory foundation conditions and that an attempt to improve the foundations was made by providing pile support. Nevertheless, it does not appear that the mere use of piles, even including batter piles, was sufficient to prevent excessive movement of the walls.

Fig. 4 shows the foundation and backfill materials associated with those walls that experienced progressive outward or tilting movements. It may be observed that in every reported example of progressive movement where there was sufficient information to classify the soils, clay occurred in the foundation or in the backfill, and in most instances occurred in both. This suggests that present design procedures and those that have been used in the past must be quite conservative when foundation conditions are good and when the backfill consists of sand or gravel. On the other hand, it also suggests that the factor of safety of walls founded on clay or backfilled with clay is probably on the average much lower than believed by the designers.

An Interesting Example

The first example is illustrated in Fig. 5 which shows the pertinent data concerning one of a pair of open abutments constructed for a grade separation. It was recognized that the foundation for the abutments would require pile support and the structure was founded upon cast-in-place concrete piles having an embedment of 45 ft. One group of four of these piles was tested with the results shown in the figure. On the basis of the test, it appears that the average shearing resistance of the soil was approximately 0.17 ton per sq. ft.

To lighten the load on the abutments as much as possible and at the same time to reduce the active earth pressure of the railroad embankment, the abutments were made hollow and it was specified that the fill should slope downward toward the toe. In spite of these precautions, each abutment began to settle during construction and when the total dead load reached 5000 tons each abutment began to tilt toward the fill and to sink into the ground. At this stage the average settlement increased very rapidly from 4 in. to almost 10 in., whereupon the fill was removed and the design altered in such a way that no fill rested upon the bases of the abutments when the bridge was completed.

On the assumption that the average shearing resistance of the soft subsoil was 0.17 ton per sq. ft., the total ultimate bearing capacity of the base of the abutment should have been approximately 5300 tons. This value is in reasonable agreement with the observed load at failure. Hence, it appears quite obvious that the failure of the abutment was caused by overloading the subsoil and that it had little if any relation to the active earth pressure against the abutment.

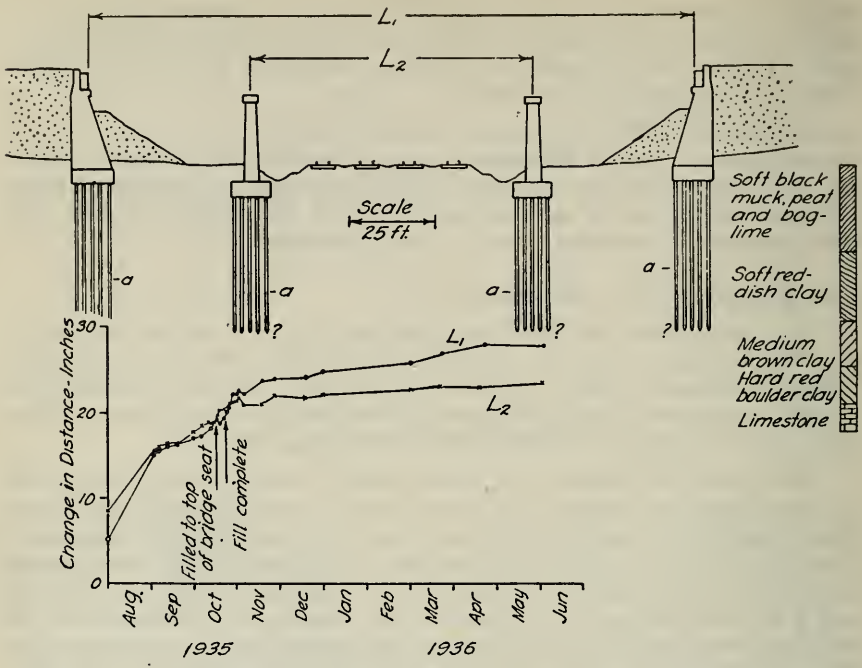


Fig. 6.—Progressive Movement of Piers and Abutments.

Fig. 6 shows the pertinent data concerning a typical example of progressive forward movement of large magnitude. The piles may have penetrated the soft material and rested on the medium clay at a depth of 40 ft., but the records indicate that more likely they terminated near the points marked *a*, within the soft clay deposit.

The two abutments and two intermediate piers for the bridge were completed and backfilling was in progress when movements of all four elements of the substructure were observed. Measurements were made with the results indicated on Fig. 6. It may be noted that the distance L_2 between the intermediate piers decreased almost as much as the distance L_1 between abutments. This means that the movement was deep-seated and involved the lateral squeeze or flow of clay toward the center of the bridge from each end. Such a movement could hardly be caused other than by overloading the clay stratum by the weight of the backfill. Under the weight of the fill, the bearing capacity of the soft reddish clay and overlying material was probably approached and a slow lateral flow or creep was initiated by the excessive shearing forces. The lateral pressure against the abutment was probably not excessive because the abutments were of the open type and the fill was allowed to extend through them.

Lateral Forces May Be Very Great

This example demonstrates that the lateral forces acting against a vertical section through an abutment supporting a high fill may be very great, considerably greater than the forces due to the active earth pressure against the abutment itself. This fact was demonstrated clearly by the behavior of a structure built during the war to store

iron ore. The structure consisted of two parallel retaining walls about 30 ft. high and 275 ft. apart. The walls were tied to each other by a series of steel rods located just below the ground surface. A deep deposit of medium clay was located beneath the structure. The behavior of the walls was observed by means of strain observations on the tie rods. At the yield point of the rods, their capacity to resist the horizontal forces against the retaining walls was 70,000 lb. per lin. ft. of wall. When the iron ore was piled to a height of 22 ft., the rods reached their yield point strain. Yet, according to any rational method of computation, the active earth pressure of the ore against the walls could not have exceeded about 16,000 lb. per lin. ft. Therefore, the actual horizontal forces exerted against the walls and their foundations were over four times the computed earth pressures. Independent observations demonstrated that the ultimate bearing capacity of the clay beneath the storage yard was 2.6 tons per sq. ft., whereas the weight of 22 ft. of ore was 1.8 tons per sq. ft. Therefore, the factor of safety against a bearing capacity failure was only about 1.4. At such a low factor of safety, excessive and continuous horizontal deformations in the subsoil are to be expected.

In a large number of the other examples of progressive outward movement or tilting, conditions appeared to be similar to those indicated in Fig. 6 except that the movements were generally much smaller. This would suggest that the shearing stresses in the foundation were considerably smaller with respect to the shearing strength of the soil than in the example described. Nevertheless, in practically all of the examples it is believed that the lateral forces in the subsoil of the structure were considerably greater than the computed active earth pressure. Progressive movements were even observed on several walls supported by fairly stiff clays.

Effect of Increased Live Loads

In a number of instances, progressive movements seemed to begin in the 1930's in spite of the fact that the walls had been apparently static for many years before. This was generally attributed by the railroad engineers to the marked increase in locomotive weights during this period. Many of the walls were designed for Cooper E–30 or E–40 loading, whereas by the 1930's the weight of motive power had generally increased the loading to E–60 or E–70. It is quite possible that this increase in live load, with accompanying increase in toe pressures, was responsible for the initiation or revival of movements. However, there is no satisfactory way to evaluate the relative importance of this factor.

In most instances where both the backfill and foundation consisted of clay, it was not possible to ascertain the relative importance of those movements associated with overloading the clay foundation and those that may have been caused by the progressive decrease of the strength of the backfill material. The evidence appears to indicate that foundation failures or foundation movements were more prevalent than those caused by an increase in the backfill pressure of clay. However, several of the complete failures undoubtedly belong in the latter category and it is certain that clay backfills in several instances did exert an increasing pressure.

In two examples concrete gravity walls were built to retain clay fills sloping at 1½ to 1 upward and away from the crest of the wall. In one case, the top of the fill was about 8 ft. above the top of the wall and the wall itself was 8 ft. high. In the other, the wall was only 6 ft. high and the fill was about 60 ft. high. Both walls were stable for a number of years. Both walls failed structurally at a point above the foundations. This fact indicates that deep-seated foundation movements could not have been the primary cause of failure. Hence, it must be inferred that the pressure of the clay gradually increased until failure occurred.

Conclusions

The records obtained by means of the questionnaire are still being studied and analyzed. However, it is believed that several rather definite conclusions can be drawn at the present time.

1. Considering the total number of conventionally designed retaining walls and abutments, failure or progressive movement is a relatively uncommon occurrence.

2. Unsatisfactory behavior is rarely encountered unless the subsoil of the wall, or its backfill, or both, contains clays or clay-like materials. The most prevalent cause of trouble is the overloading of clay foundations by the weight of the backfill. The second most common cause is probably the gradual increase of pressure when the backfill material consists of clay. A possible third cause of some importance is the increase of live load.

3. Contrary to the opinion of some engineers, it seems doubtful that the effects of vibration due to traffic on granular backfills are of serious importance. Otherwise it is probable that more difficulties would have been reported with walls backfilled with sand.

4. The unsuccessful behavior of walls has been due primarily to misjudgment of the foundation conditions. Present methods of design place the emphasis almost exclusively on computed earth pressures that often have little relation to the real forces that the structures must resist. In the future, much more attention should be given to the foundation conditions and to possible time-conditioned changes that may occur in the backfill. The theoretical study of earth pressures has provided a fascinating diversion for engineers, but it has tended to blind them toward an understanding of the real behavior of earth-retaining structures.

Discussion on Iron and Steel Structures

(For Report, see pp. 199–235.)

(President Mottier presiding)

Chairman E. S. Birkenwald (Southern): During the past year Committee 15 has lost an active and interested member in the death of Roy Alexander Kane, whose memoir is given on page 200. The members of the committee take this opportunity to express their sincere regrets.

Of the seven assignments, Committee 15 offers reports on five, two of which are final. In some of these reports, all or part are recommendations for revision of the Manual. Each recommended revision, unless editorial, has been voted on by the voting members of the committee, in which better than a two-thirds majority sustained the revision.

The report on Assignment 1, submitted for adoption and publication in the Manual, will be presented by Mr. C. E. Webb, chairman of the subcommittee.

Mr. C. H. Sandberg, chairman of the Subcommittee for Impact and Bridge Stresses, will discuss revision of article 306 of the Specifications for Steel Railway Bridges when it is considered for adoption. Mr. Webb!

C. E. Webb (American Bridge Company): The report of Assignment 1—Revision of Manual—recommends the following:

On page 15–4, in paragraph 104, add at the end of the paragraph:

"Where shallower depth spans are required, they shall be proportioned so that all deflection from the combined effect of live load and impact shall not exceed that obtained for spans of the depth ratios given above."

If you refer to your specifications, you will find that is the economical depth. This is to keep the deflection of the shallower spans within the economical depth. I move the adoption of this change.

(The motion was seconded.)

W. E. Robey (Atchison, Topeka & Santa Fe): At the present time a good many railroads are using rolled beams for short spans, and the maximum length of bridge to be used now for rolled beams is approximately 50 ft. If you adopt this change, it will mean, even though you lessen the impact which is being considered later, you will shorten up the maximum length of span about 3 ft.

I would like to ask the committee what information it has that this 1/15 is the thing to use. Why shouldn't it be 1/14 or 1/16?

Chairman Birkenwald: The reason for making this change in the specification comes about because of our dealings with various federal and state highway department agencies in the design of underpass structures.

Prior to 1935 the specification was written very much as we are trying to revise it today. The specification was mandatory. In 1935, when the new specifications came out, and which we are using today, the word "preferably" was used, and the state highway departments and the federal agencies have used the word "preferably" as an open door to depth ratios that are considerably greater than what we consider are preferable. And for the purpose of strengthening the hand of the bridge engineer, we are proposing to revise this article, to make it mandatory.

(Mr. Webb's motion was then put to a vote and carried.)

Mr. Webb: Article 206—Page 15–7 deals with impact. We have a special subcommittee on impact, of which Mr. Sandberg is chairman, and I think he should make his comments before we adopt or reject this.

C. H. Sandberg (Atchison, Topeka & Santa Fe): Tuesday morning, in their addresses, you heard Mr. Chinn and Mr. Aydelott mention the large program of research that is carried on by your Association, also of putting into use the results of this research.

The revisions we are proposing on impact in the design specification are some concrete results of a large program of research that has been going on since 1940.

I might say that your Association since 1940, and including this year, has appropriated over $215,000 for research on impact.

The revisions we are proposing are printed on pages 200 and 201. On pages 207 to 212 is a statement in support of these changes, also table and graphs. Fig. 1 on page 209 shows that the impact for beam and girder spans under steam locomotives is being reduced for spans up to 100 ft.

Fig. 2, page 210, covers impact for truss spans. For all lengths of spans, the impact is being increased. Fig. 3 has to do with equipment without hammer blow and covers spans of all types. And the impact for these spans, under this type of loading, is being increased.

As mentioned in the statement, these revisions are the result of approximately 2000 tests. We feel that it is a worthwhile revision, and it will be of advantage to the railroads.

I move that Article 206, paragraph (b), as printed on pages 200 and 201, be accepted for publication in the Manual.

(The motion was seconded.)

Mr. Robey: A good many railroads have bridges that are located in slow speed territory, and terminals where you have very little, if any, impact. I know that practically all of us arbitrarily reduce the impact when we design these structures.

I should like to ask the committee if it is going to consider or have considered legalizing that by making some statement in our impact specifications.

Mr. Sandberg: That is a good point, Mr. Robey. I would like to say that next year the committee is going to study impact as related to the rating of bridges, and at that matter has been thoroughly decided by the committee, undoubtedly we will want to recommend some change or addition to the present specification, making some allowance when the speed is reduced, or when it is not at critical speed.

(Mr. Sandberg's motion was put to a vote and carried.)

Mr. Webb: The next two revisions of the specification cover various grades of steel, such as structural, carbon, silicon, nickel, steel forgings, cast iron, malleable iron castings, wrought iron and bronze. They run various sections 8 to 17. These revisions are not really revisions. This is merely a cutting down of what is in the specifications at the present time. We are working with ASTM specifications for these different grades of steel, those references being made in our own specifications. We have given under each grade of steel the pertinent information that is desired by the designer or bridge engineer, such as chemical composition, the tensile strength requirements, the cross head speed of the machine, and the bend of test specimen, which are more pertinent, and putting them in the specification makes them handy for the designer. Otherwise they can refer to the ASTM for the extra requirements for the specifications, and this saves space.

There is practically no change on 801. Structural Steel, or 901. Structural Silicon, except on page 203 there is an editorial change which is caused by the ASTM rescinding the permission to weld silicon steel about a month ago. So, we wish to delete the time we will thrash out the matter of reduced speed or speeds not as critical. After this paragraph on page 203 stating:

"Repair by welding, if necessary, shall be undertaken only after inspection and approval by the engineer or his representative."

And substitute:

"Material repaired by welding will be rejected." That means no silicon steel can be repaired by welding.

Going to X High-Tensile Structural and Rivet Steel, that has been left out for the time being because new specifications are being written. That will be submitted later for approval.

Structural Nickel Steel appears under XI; Steel Forgings under XIII; Cast Iron under XIV; Malleable Iron Castings under XV; Wrought Iron under XVI, and Bronze under XVII. They all refer to the ASTM designation for the remaining information not given in our specifications.

Also Section XVIII is the same as now being printed in the specifications covering alloy steels. This is added to the specification. It is under XVI in the present specification but now becomes XVIII under the new one.

Grouping these as a whole, I move the adoption as given in the committee's report.
(The motion was seconded, put to a vote and carried.)

Mr. Webb: On page 15–95 to 15–100, incl., Specifications for Erection of Steel Railway Bridges: They were adopted prior to ten years ago and we therefore submit these for reapproval without change. This also pertains to pages 15–133 covering Track Anchorage on Bridges and Similar Structures. That is for adoption without change. That has been in for over ten years.

Also pages 15–119 and 15–120 covering Classification of Railway Bridges is submitted with only one change, which is an editorial change.

Page 15–119—Delete paragraphs 1 and 2 and substitute the following:

(He read the two paragraphs at the top of page 207.)

Mr. Webb: Also on page 15–119 under the heading Division of Subject, delete the figure 3 in the first line. That is caused by deleting the first two paragraphs.

I move the reapproval of these sections as modified.

(The motion was seconded, put to a vote and carried.)

Mr. Webb: That completes the report on Assignment 1.

Chairman Birkenwald: On page 212 there is a final report submitted as information, and it includes a recommended revision of the section of the Manual on Fusion Welding, page 15–133.

The report is brief, and I take it that you have all read it, and there is no reason to read it.

The recommended revision of the section of the Manual is on page 213 entitled Fusion Welding 1948.

I move the adoption of this revision to the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Birkenwald: A progress report on Assignment 5, presented as information, will be given by Mr. G. L. Staley, chairman of the subcommittee on design of bridge details. Professor M. B. Lagaard will discuss his report of a bridge rocker shoe assembly test occasioned by a controversy concerning the interpretation of one of the articles in the steel railway bridge specifications. Mr. Staley!

G. L. Staley (Missouri–Kansas–Texas): As stated by Mr. Birkenwald, this report consists merely of a progress report of a test on a bridge rocker shoe assembly. The reasons for making the test are set forth in the three or four short paragraphs which I need not read. The test was made by Professor Lagaard at the Northwestern Technological Institute, and he will now present the report of his test. Professor Lagaard!

M. B. Lagaard (Northwestern Technological Institute): I am not going to spend much time explaining this test. It was brought up by Jonathan Jones who pointed out that, by one method of analysis, you would get a thickness for the steel slab under the rocker shoe, of about 3 in. in one particular case and, by another method which gave the limiting thickness as half the width, you got 11 in. So there was quite a difference in the results of the two methods of design.

In checking over the method of analysis, it was found there was some discrepancy and some difference of opinion as to what the actual pressures were under the slab, and as between the slab and the concrete. Many just assumed they were uniform, knowing, of course, they were not quite uniform but hoping or assuming they were not very far off when they assumed they were uniform.

So this committee, a group of men, developed a method of analysis which permitted us to find out what these pressures were. In so doing, by the use of steel blocks under the slab, resting on the concrete, and measuring the deformation of the box by means of electrical strain gages, we were able to find out the actual pressures varied from zero at the corners to a maximum, at the center, of about five times what we actually assumed was the uniform pressure. In other words, assuming 4000 psi. as uniform, we actually measured under the center of this bearing over 20,000 psi.

That gave us the nucleus for proposing some more tests in which we will vary the thickness of the slab, using various thicknesses and various widths and also various bedding conditions. We hope by making some additional tests we can develop a design that will be fairly satisfactory, giving probably a smaller bearing area, a higher average bearing pressure but a lower ultimate pressure.

I might point out here that while we have pressures of 2000 psi., as indicated by these tests, of course, the concrete is confined, and we haven't the same serious problem there. So these tests we are proposing to make during the next year, if agreed to by the committee, will be made, and with that information we hope to develop a satisfactory design formula.

President Mottier: Thank you, Professor Lagaard.

Chairman Birkenwald: The final report on Assignment 6, submitted for adoption and publication in the Manual, will be presented by Mr. A. B. Chapman, chairman of the subcommittee on shortening of eyebars to equalize the stress.

A. B. Chapman (Chicago, Milwaukee, St. Paul & Pacific): Shortening of eyebars to equalize the stress was presented by your committee as information last year and published in the Proceedings Vol. 48, 1947, page 969 to 986, incl. From this material, recommended practice for the shortening of eyebars is now submitted as a final report of your committee with the recommendation that it be adopted and published in the Manual. I move its adoption for publication in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Birkenwald: A progress report on Assignment 7, presented as information, will be given by Mr. R. A. Van Ness, chairman of the subcommittee on specifications for cold riveted construction.

R. A. Van Ness (Atchison, Topeka & Santa Fe): Subsequent to the publication of this bulletin, the Research Council on Riveted and Bolted Structural Joints held a meeting at which it was decided to delete the words "hot and cold" noted under Project 1.

A resolution was adopted, namely: It is the intention of the Council to test both hot and cold driven rivets where it is considered the testing will develop significant differences or valuable information.

Small diameter rivets have been driven cold for many years, but cold driving of large diameter rivets is a reasonably new development and calls for pressure controlled equipment which is attached to the penumatic or hydraulic riveting machine. Driving rivets cold offers a worthwhile saving in shop fabrication cost. At this time it appears there will be no practical application of this method in bridge erection riveting.

However, in 1933, cold driving of large diameter rivets was successfully undertaker in connection with the erection of a 10,000,000-cu. ft. gas holder by McClintock Marshall for the Philadelphia Gas Works. Cold driving was followed in production in 1936 at the

Lachine Works of the Dominion Bridge Company of Canada, after extensive experimental work and research. Cold driving of large diameter rivets is increasing in the United States.

To date the method has not been used in either country on any major railway bridge structures. When tests now under way on bulldozed hot and cold riveted joints are completed and analyzed, possibly late this summer, Committee 15 will decide if a specification for cold riveted construction shall be compiled and submitted to the Association.

This is a progress report submitted as information.

Chairman Birkenwald: That concludes the report of Committee 15—Iron and Steel Structures.

President Mottier: Gentlemen, this committee has been noted for a long time for its thorough work and, you might add to that this year, the volume of its work.

The committee is excused with our thanks. (Applause)

Discussion on Clearances

(For Report, see pp. 273–275.)

(President Mottier presiding)

Chairman J. E. South (Pennsylvania): Before presenting the report of Committee 28, I wish to thank the members of the committee for their cooperation and for the effort that they have put forth in solving the problems that we were assigned.

Your committee had four subjects for study this past year, and we are prepared to report on three of these subjects. The first assignment, Revision of Manual, was handled by a subcommittee of which Mr. J. E. Fanning was chairman. Mr. Fanning, will make the report of that committee.

J. E. Fanning (Illinois Central): Your committee has reviewed the recommended practices as to clearances now appearing in the Manual which were adopted in 1936 and revised in 1938, when the width of the equipment diagram, unrestricted for main lines, was increased from 10 ft. 7 in. to 10 ft. 8 in., and the height of the diagram above the top of rail was reduced from 4 in. to 2½ in.

A number of suggestions have been received by your committee for changes in these diagrams, several of which called for increased clearances.

In the report of the special committee in 1936, it was pointed out that the logical course is to prescribe minimum clearance only, and to place no restrictions whatever as to maximum clearances.

The clearances now shown by diagrams 9 and 10 in the Manual have been adopted by the Association of American Railroads, Operation and Maintenance Department, Mechanical Division, and Figs. 1 to 8, incl., appear regularly in the issues of the publication, Railway Line Clearances of Railroads in the United States, Canada, Mexico and Cuba.

For these, and other reasons, your committee hesitates to recommend changes which call for increase in clearances. Your committee, however, recommends the following minor revisions which are shown on pages 273 and 275.

(Mr. Fanning then read the revisions under assignment 1.)

Mr. Fanning: I move the adoption of these minor revisions.

(The motion was seconded, put to a vote and carried.)

Chairman South: Assignment 2—Clearances as affected by girders projecting above top of track rails, structures, third rail, signal and train control equipment, collaborating with Signal and Electrical Sections, Engineering Division, and with Mechanical and Operating–Transportation Division, AAR: We have done considerable work on this subject but, due to the fact that additional information has to be compiled, it will be impossible to report on this subject at this time. Assignment 3 was handled by Mr. A. R. Harris, who is also vice-chairman of Committee 28.

A. R. Harris (Chicago & North Western): Your committee has revised Fig. 7, Clearance Diagrams for Platforms, page 28–8, and submits the revision of Fig. 7 for approval and Fig. 8 for reapproval. I move that Fig. 7 and 8 be accepted for publication in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman South: Mr. C. D. Horton is chairman of a subcommittee handling Assignment 4, which is the compilation of the railroad clearance requirements of the various states. Mr. Horton has been unable to attend the convention. I am going to ask Mr. R. C. Nissen, to report on this assignment.

R. C. Nissen (Southern Pacific): The report is submitted as information. Your committee has felt the need for a ready reference to clearance requirements, in view of the increasing agitation for revisions to existing laws and for new regulations in states where they do not now exist.

The material shown in the tabulation was gathered through inquiries of public bodies having jurisdiction in the various states, by review of the statutes, and contacts with railroads operating in all states and in Canada. This report does not purport to show all details and ramifications of existing requirements but an attempt has been made to set forth the general and basic clearances.

Since submission of this report, the state of California has adopted a new clearance regulation, and other states are giving like consideration. Your committee proposes to currently revise the report to reflect these and other changes and expand the tabulation when new information shows such action to be desirable.

President Mottier: Thank you, Mr. Nissen.

Chairman South: That concludes the report of Committee 28.

President Mottier: Thank you, Mr. South, and your committee for your excellent report on this very important subject.

The committee is excused with the thanks of the Association. (Applause)

Discussion on Wood Bridges and Trestles

(For Report, see pp. 269–272.)

(President Mottier presiding)

Chairman S. F. Grear (Illinois Central): We have only one subject to report on this year, but we have two subjects that have had considerable study, and the chairmen of those subcommittees would like to make some very brief remarks to you.

I am going to call on Mr. Showalter to discuss Assignment 5—Specifications for inspection of timber trestle railway bridges.

J. R. Showalter (Missouri Pacific): The subject is a little ambiguous, it seems to me, in the term "specification." We rather think of specification as a well defined treatise which sets up definite bonds of inspection and procedure. I thought possibly the term "instructions," "general instructions" would be better. However, that is a minor point.

This committee proposes to bring you the various instructions that have been issued. With that line of thought, we have contacted various railroads and have received numerous replies.

We find quite a difference in the instructions which have been issued by these various railroads. We also find that some railroads have no definite instructions covering this inspection. It is not our thought that we are going to try to revolutionize or radically change a lot of these instructions. We do expect to review them and, in some cases, bring them up to modern procedures.

The one thing that we thought we could be helpful in is to give more detailed instructions covering treated timbers. Most of our railroads have treated timbers now which have been in structure for as long as 25 and 30 years, and we are at the point where these structures or certain members are being replaced.

All this timber that has been in as much as 20 years should be given careful inspection. Consider the case of timber piles which were driven in the early days. The treatment was not as effective as it is today, and we did not make proper treatment of the caps. There is a great variance between the divisions on our road as to the method of taking care of the resulting situation. Some of them are posting these piles in structures which are on curves, and which are subjected to drift from high water, when it is questionable whether that should be done. In other words, a pile that has 3 or 4 in. of sound timber, in many cases, is much better than a post.

In addition to detailing the method of inspection, we had also thought we would digress a little and bring in some information and suggested instructions covering repairs of that kind. We have gone into this in a very preliminary manner so far, but we think that we will be able to offer something which will be helpful and wnich we would like to present for your consideration at the next meeting.

President Mottier: Thank you, Mr. Showalter.

Chairman Grear: Mr. W. C. Schakel wants to say a few words about methods of fireproofing wood bridges and trestles, including fire-retardant paints.

I think Mr. Schakel wants to ask you for some help.

W. C. Schakel (Cleveland, Cincinnati, Chicago & St. Louis): The subcommittee on Assignment 6 in delving into this subject of methods of fireproofing wooden bridges and trestles has found that very little fireproofing of structures is being done by the various railroads. We did obtain some information from the railroads on several methods, particularly methods like shielding with metal.

Another method is the covering of the caps and the stringers. Still another method is the application of some inert material such as gravel or slag, applying it on top of brushed coats of mastics. There are several patented methods for this, and one or two of the railroads have reported on those. We have not put out any direct inquiry, but the committee probably will in the next year make inquiries of all the railroads as to the method being used by them.

In the matter of fire-retardant paints, our investigation indicates that most of these materials are for inside use. They are for buildings primarily, and in most cases are water-mixed paints which, if used outside, would bleach out very quickly, or at least in a time so short that they would not be of value on bridges and trestles.

If there was a material that would answer our purpose, this would apparently be a much better method of fire-proofing than the application of materials on the decks, in that it would also protect the piling and the stringers and caps from fire below. The deck treatment, of course, only protects from the usual causes, the dropping of hot coals or hot bricks or things of that kind.

Chairman Grear: Assignment 7—Design of creosoted timber pile piers for long spans: We have a report to make, and that will be given by Mr. C. V. Lund, chairman of that subcommittee.

C. V. Lund (Chicago, Milwaukee, St. Paul & Pacific): The report is brief, and I will read it.

(Mr. Lund then read the report on Assignment 7.)

Mr. Lund: Figs. 1 and 2 to which reference is made precede the text as printed in the report.

Mr. President, it is recommended that these plans be acted upon for adoption and printing in the Manual as recommended practice. I so move.

(The motion was seconded, put to a vote and carried.)

Chairman Grear: Mr. President, this concludes the report of Committee 7.

President Mottier: Thank you, Mr. Grear. I think this concludes your term as chairman of this committee, and we wish to thank you for your leadership.

We wish to thank the committee for their work. I think you have some very good assignments. If you can bring up something that we can spray on a bridge and keep it from burning up, you will have done a real job for the railroads of this country. The committee is excused with the thanks of the Association.

MONOGRAPHS

Impact Tests on Two Truss Spans

Toledo Terminal Railroad

1. Digest

This report embraces a description and analysis of tests made on one 142-ft. deck span and one 250-ft. through draw span of the Toledo Terminal Railroad. The tests were made under steam locomotives and freight cars operating over a complete range of speeds from 10 mph. up to 43 mph. which was the maximum allowable speed in this territory. The tests were made at the request and at the expense of the Toledo Terminal Railroad for the purpose of determining the carrying capacity or rating of the steel superstructure by strain gage readings.

The stresses were measured in representative members of both spans under regular scheduled trains at low speeds as well as under test trains over the complete range of speeds. Stresses were measured under a total of 178 test trains on the two spans. The procedure in securing the runs with the special test train was to stop a regular scheduled freight train for about 30 min. and run the locomotive, tender and first four cars back and forth over the bridge at the various speeds.

The stresses were measured by means of electromagnetic strain gages with oscillograph recording on sensitized photographic paper and every care was taken in calibrating the instruments and conducting the tests; hence it is believed that the results can be accepted with full confidence.

The results of these tests are of particular value to bridge engineers for they afforded a comparison of the simultaneous strains in several members of a truss as well as simultaneous stresses at the four corners of built-up members of the trusses.

The data were analyzed principally for the purpose of determining the carrying capacity of the span but the data were also analyzed for the purpose of studying the magnitude of the individual effects which make up the total impact.

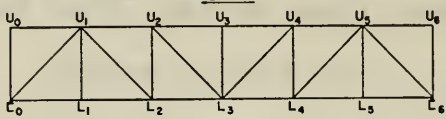
A brief summary of the analysis of the data as found from this study is as follows:

1. There was considerable variation between the stresses recorded in the chord members of the 142-ft. deck span under the trains crossing the bridge at 10 mph. and those calculated for the same load and position of load (see Table 1). The variation between the actual and calculated stresses is believed to be due to the action of the stringers in taking direct stress. This action decreases the stresses in the top chord of the deck span and increases the stresses in the lower chord. There is fair agreement between the actual and calculated static stresses in the web members.

There was good agreement between the recorded and calculated stresses in the chord and web members of the 250-ft. draw span (see Table 2). The calculated stresses were based on the continuous action of a two-span structure of constant moment of inertia. It was assumed that the center panel over the rim-bearing support could transmit moment but no shear. It appears that if the wedges are properly adjusted, the determination of stresses can be based upon these assumptions.

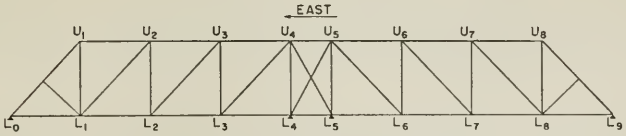
TABLE I
COMPARISON OF RECORDED AND CALCULATED STATIC STRESSES
SPAN 7
142'-0 DECK TRUSS SPAN

EAST



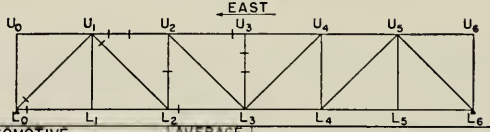
NUMBER OF GAGES ON MEMBER	MEMBER	LOCOMOTIVE NUMBER	LOCOMOTIVE CLASS	DIRECTION	STATIC STRESS RECORDED	STATIC STRESS CALCULATED	STRESS FACTOR RECORDED / CALCULATED	
COLUMN 1	2	3	4	5	6	7	8	9
4	$L_0\ U_1$	1095	K	WEST	-7.32	-5.94	1.23	1.22
		1125	K1	WEST	-6.45	-5.73	1.13	
		1125	K1	EAST	-7.98	-6.14	1.30	
	$U_1\ L_2$	1094	K	WEST	+6.62	+6.43	1.03	1.04
		1095	K	WEST	+6.70	+6.28	1.07	
		1094	K	EAST	+7.48	+6.86	1.09	
		1095	K	EAST	+6.53	+6.77	0.97	
	$U_2\ L_2$	1094	K	WEST	-5.42	-5.90	0.92	1.00
		1095	K	WEST	-5.69	-6.17	0.92	
		1095	K	EAST	-7.56	-6.39	1.18	
		1094	K	EAST	-6.33	-6.47	0.98	
	$U_3\ L_3$	1125	K1	WEST	-6.52	-6.98	0.93	0.92
		1125	K1	EAST	-6.89	-7.11	0.97	
		1125	K1	EAST	-6.18	-7.15	0.87	
	$U_1\ U_2$	1095	K	WEST	-5.60	-7.15	0.78	0.81
		1125	K1	WEST	-5.52	-6.96	0.79	
		1125	K1	EAST	-6.21	-7.29	0.85	
	$U_2\ U_3$	1125	K1	WEST	-5.03	-7.12	0.71	0.75
		1125	K1	EAST	-5.26	-6.59	0.80	
		1125	K1	EAST	-5.24	-7.00	0.75	
	$L_0\ L_1$	1095	K	WEST	+5.47	+6.34	0.86	0.93
		1125	K1	WEST	+5.83	+6.10	0.96	
		1125	K1	EAST	+6.47	+6.58	0.98	
	$L_2\ L_3$	1094	K	WEST	+9.12	+6.85	1.33	1.31
		1095	K	WEST	+8.63	+6.53	1.32	
		1094	K	EAST	+9.01	+6.70	1.34	
		1095	K	EAST	+8.15	+6.61	1.23	
2	$L_0\ U_1$	1289	H3	WEST	-7.55	-6.97	1.08	1.10
		1095	K	EAST	-6.83	-6.12	1.12	
	$U_1\ U_2$	1095	K	WEST	-6.04	-7.55	0.80	0.77
		1095	K	EAST	-5.46	-7.36	0.74	
	$U_2\ U_3$	1289	H3	WEST	-6.90	-8.65	0.80	0.79
		1095	K	WEST	-5.98	-7.55	0.79	
		1095	K	EAST	-5.26	-6.82	0.77	
	$L_0\ L_1$	1095	K	WEST	+4.69	+6.73	0.70	0.70
		1095	K	EAST	+4.56	+6.56	0.70	
		1289	H3	WEST	+5.28	+7.45	0.71	
	$L_2\ L_3$	1095	K	WEST	+7.62	+7.01	1.09	1.03
		1094	K	WEST	+6.56	+6.93	0.95	
		1095	K	EAST	+6.92	+6.50	1.07	
		1115	K1	EAST	+7.31	+6.74	1.09	
	$U_1\ L_2$	1289	H3	WEST	+6.91	+6.80	1.02	0.99
		1095	K	WEST	+5.88	+5.93	0.99	
		1115	K1	WEST	+5.20	+5.30	0.98	
		1095	K	EAST	+6.61	+6.76	0.98	
		1115	K1	EAST	+6.70	+6.88	0.97	
	$U_2\ L_2$	1095	K	WEST	-5.20	-6.10	0.85	0.87
		1095	K	EAST	-5.59	-6.37	0.88	
	$U_2\ L_3$	1095	K	WEST	+2.70	+3.61	0.75	0.77
		1115	K1	WEST	+2.03	+2.71	0.75	
		1289	H3	WEST	+3.06	+3.81	0.80	
		1095	K	EAST	+4.24	+5.41	0.79	
		1115	K1	EAST	+4.09	+5.36	0.76	
	$U_3\ L_3$	1095	K	WEST	-6.89	-7.02	0.98	0.93
		1095	K	EAST	-6.14	-7.18	0.86	
		1289	H3	WEST	-6.61	-7.07	0.94	
1	FLOOR BEAM U_3	1095	K	WEST	+9.38	+8.36	1.12	1.08
		1094	K	WEST	+8.50	+8.70	0.98	
		1115	K1	WEST	+9.11	+8.43	1.08	
		1095	K	EAST	+9.25	+8.53	1.08	
		1094	K	EAST	+9.25	+8.53	1.08	
		1115	K1	EAST	+9.25	+8.33	1.11	
1	STRINGERS $U_2\ U_3$	1095	K	WEST	+7.24	+9.17	0.79	0.76
		1094	K	WEST	+6.96	+9.45	0.74	
		1115	K1	WEST	+7.18	+9.28	0.77	
		1095	K	EAST	+7.18	+9.50	0.76	
		1094	K	EAST	+6.69	+9.17	0.73	
		1115	K1	EAST	+7.02	+9.05	0.78	

TABLE 2
COMPARISON OF RECORDED AND CALCULATED STATIC STRESSES
SPAN 6
250'-0 THRU DRAW SPAN



NUMBER OF GAGES ON MEMBER	MEMBER	LOCOMOTIVE NUMBER	LOCOMOTIVE CLASS	DIRECTION	STATIC STRESS RECORDED	STATIC STRESS CALCULATED	STRESS FACTOR RECORDED / CALCULATED	
COLUMN 1	2	3	4	5	6	7	8	9
4	$U_6\ U_7$	1095	K	WEST	−6.06	−6.31	0.96	0.96
		1094	K	WEST	−5.45	−6.09	0.90	
		1094	K	EAST	−6.44	−6.25	1.03	
	$U_4\ U_5$	1092	K	WEST	−2.80	+2.60	1.08	1.10
		1115	KI	WEST	+2.33	+2.12	1.10	
		1095	K	EAST	+2.48	−2.24	1.11	
	$L_6\ L_7$	1095	K	WEST	+2.38	+3.08	0.77	0.84
		1095	K	WEST	−2.46	+2.67	0.92	
		1095	K	EAST	+3.18	+3.78	0.84	
	$U_6\ L_7$	1095	K	WEST	−5.36	+5.29	1.02	1.09
		1094	K	WEST	+5.84	+4.85	1.20	
		1094	K	EAST	+6.34	+5.96	1.06	
	$U_6\ L_6$	1095	K	WEST	−3.38	−3.52	0.96	0.95
		1095	K	EAST	−4.00	−4.31	0.93	
	$U_5\ L_6$	1095	K	WEST	+6.36	+6.44	0.99	1.04
		1115	KI	WEST	+6.29	+5.92	1.06	
		1137	KI	EAST	+6.37	+5.98	1.06	
	$U_5\ L_5$	1095	K	WEST	−4.58	−5.69	0.81	0.82
		1115	KI	WEST	−4.49	−5.32	0.84	
		1137	KI	EAST	−4.28	−5.37	0.80	
2	$U_8\ L_9$	1095	K	WEST	−5.47	−4.75	1.15	1.12
		1094	K	WEST	−5.03	−4.66	1.08	
		1092	K	WEST	−4.97	−4.63	1.07	
		1137	KI	WEST	−5.14	−4.56	1.13	
		1094	K	EAST	−4.84	−3.97	1.22	
		1092	K	EAST	−4.51	−4.13	1.09	
		1137	KI	EAST	−4.45	−4.04	1.10	
	$U_6\ U_7$	1092	K	WEST	−6.11	−6.05	1.01	1.05
		1137	KI	WEST	−6.57	−5.84	1.12	
		1092	K	EAST	−6.56	−6.30	1.04	
		1137	KI	EAST	−6.69	−6.64	1.04	
	$U_4\ U_5$	1092	K	WEST	+1.92	−2.28	0.84	0.96
		1137	KI	WEST	+1.96	−2.42	0.81	
		1092	K	EAST	+2.03	−2.09	0.97	
		1137	KI	EAST	−2.55	−2.11	1.21	
	$L_6\ L_7$	1092	K	WEST	+3.71	+3.04	1.22	1.11
		1137	KI	WEST	+3.33	+2.88	1.16	
		1092	K	EAST	+4.15	+4.12	1.01	
		1137	KI	EAST	+4.26	+4.08	1.04	
	$U_7\ L_8$	1092	K	WEST	−4.00	−3.90	1.03	1.08
		1137	KI	WEST	−4.06	−3.74	1.09	
		1092	K	EAST	−2.52	−2.37	1.06	
		1137	KI	EAST	−2.56	−2.28	1.12	
	$U_7\ L_7$	1092	K	WEST	+3.01	−2.84	1.06	1.11
		1137	KI	WEST	+2.57	+2.72	0.95	
		1092	K	EAST	+2.10	+1.73	1.22	
		1137	KI	EAST	+2.00	+1.66	1.20	
	$U_6\ L_7$	1092	K	WEST	+4.65	+5.06	0.92	0.89
		1137	KI	EAST	+4.01	+4.96	0.81	
		1092	K	WEST	+5.15	+6.02	0.86	
		1137	KI	EAST	+5.56	+5.78	0.96	
	$U_6\ L_6$	1092	K	WEST	−3.44	−3.58	0.96	1.05
		1137	KI	WEST	−4.25	−3.60	1.18	
		1092	K	EAST	−4.53	−4.37	1.04	
		1137	KI	EAST	−4.43	−4.36	1.02	
	$U_5\ L_6$	1092	K	WEST	+6.77	+5.73	1.18	1.10
		1137	KI	WEST	+5.65	+5.62	1.01	
		1092	K	EAST	+7.51	+6.52	1.15	
		1137	KI	EAST	+6.82	+6.46	1.05	
	$U_5\ L_5$	1092	K	WEST	−4.55	−5.12	0.89	0.88
		1137	KI	WEST	−4.58	−5.04	0.91	
		1092	K	EAST	−4.84	−5.88	0.82	
		1137	KI	EAST	−5.08	−5.79	0.88	
1	FLOOR BEAM L_6	1094	K	WEST	+8.78	+8.92	0.98	0.96
		1094	K	EAST	+8.21	+8.92	0.92	
		1115	KI	EAST	+8.76	+8.89	0.98	
	STRINGERS $L_5\ L_6$	1094	K	WEST	+6.28	+9.50	0.66	0.67
		1094	K	EAST	+6.09	+9.42	0.65	
		1115	KI	EAST	+6.60	+9.42	0.70	

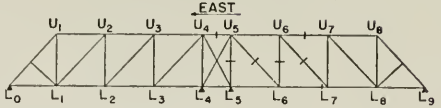
TABLE 3
SECONDARY STRESSES
SPAN 7
142'-0 DECK TRUSS SPAN
(4 GAGES ON EACH MEMBER)



MEMBER	DEPTH / LENGTH		LOCOMOTIVE			AVERAGE LIVE LOAD STATIC STRESS KIPS PER SQ. INCH	BENDING												
							HORIZONTAL AXIS					VERTICAL AXIS					80TH AXIS		
	HORIZONTAL AXIS (1-1)	VERTICAL AXIS (2-2)	NUMBER	CLASS	DIRECTION		STRESS KIPS PER SQUARE INCH	PERCENT		DERIVED ECCENTRICITY INCHES		STRESS KIPS PER SQUARE INCH	PERCENT		DERIVED ECCENTRICITY INCHES		STRESS KIPS PER SQUARE INCH	PERCENT	
COLUMN 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
L_0 U_1	0.039	0.031	1095	K	WEST	−7.69	0.33	4.3		0.16		2.16	27.9		1.14		2.25	29.3	
			1125	KI	WEST	−5.82	1.71	29.4	11.0	1.10	0.41	0.81	13.3	21.9	0.54	0.89	3.28	56.4	35.5
			1125	KI	EAST	−8.17	0.55	6.7		0.25		1.54	18.7		0.76		2.32	28.8	
			1125	KI	EAST	−8.31	0.30	3.6		0.14		2.28	27.6		1.13		2.32	27.9	
U_1 L_2	0.037	0.031	1092	K	WEST	+6.91	1.16	16.8		0.71		0.36	5.2		0.24		2.15	31.1	
			1115	KI	WEST	+7.16	1.09	15.2	17.0	0.64	0.72	0.52	7.3	7.5	0.33	0.35	2.27	31.7	32.6
			1095	K	EAST	+6.77	1.30	19.2		0.81		0.63	9.3		0.43		2.25	33.2	
			1092	K	EAST	+8.41	1.42	16.9		0.71		0.72	8.6		0.39		2.88	34.2	
U_2 L_2	0.042	0.044	1094	K	WEST	−6.18	0.50	8.1		0.23		0.65	10.5		0.59		1.00	16.2	
			1125	KI	WEST	−5.91	0.37	6.3	6.8	0.18	0.19	0.71	12.0	12.8	0.67	0.72	0.95	16.1	16.7
			1095	K	EAST	−7.56	0.45	6.0		0.17		1.07	14.1		0.79		1.39	15.6	
			1092	K	EAST	−6.69	0.45	6.7		0.19		0.99	14.8		0.83		1.27	19.0	
U_3 L_3	0.042	0.044	*1125	KI	WEST	−6.77	0.27	4.0		0.14		1.65	24.4		1.15		2.11	31.2	
			+1125	KI	WEST	−7.76	0.18	2.3	3.1	0.08	0.11	2.80	36.1	34.2	1.71	1.62	3.19	41.1	40.1
			+1125	KI	EAST	−7.31	0.40	5.5		0.20		2.68	36.6		1.73		3.40	46.5	
			+1125	KI	EAST	−7.02	0.04	0.6		0.02		2.79	39.8		1.88		2.92	41.6	
U_1 U_2	0.054	0.074	*1095	K	WEST	−5.70	0.34	6.0		0.20		0.18	3.1		0.16		0.38	6.3	
			*1125	KI	WEST	−5.33	0.37	6.9	7.0	0.23	0.23	0.04	0.7	2.8	0.04	0.15	0.75	14.1	14.0
			+1125	KI	EAST	−6.33	0.57	9.0		0.30		0.10	1.6		0.08		1.07	16.9	
			+1125	KI	EAST	−6.54	0.40	6.1		0.20		0.39	5.9		0.31		1.21	18.5	
U_2 U_3	0.054	0.074	1092	K	WEST	−5.23	0.47	9.0		0.44		0.00	0.0		0.00		1.03	19.7	
			1115	KI	WEST	−6.17	0.32	5.2	9.1	0.25	0.39	0.10	1.7	1.1	0.09	0.06	0.89	14.4	17.4
			1092	K	EAST	−5.26	0.49	9.3		0.45		0.04	0.8		0.04		1.00	19.0	
			1125	KI	EAST	−5.71	0.73	12.8		0.42		0.11	2.0		0.11		0.95	16.6	
L_0 L_1	0.053	0.072	1095	K	WEST	+5.68	1.40	24.6		0.92		0.47	8.3		0.49		1.52	26.8	
			1125	KI	WEST	+6.04	0.98	16.3	18.4	0.61	0.79	0.78	12.9	6.8	0.76	0.51	1.26	20.9	21.1
			1125	KI	EAST	+6.64	1.49	22.4		0.84		0.32	4.8		0.28		1.76	26.5	
			1125	KI	EAST	+7.09	0.72	10.2		0.38		0.08	1.1		0.07		0.73	10.3	
L_2 L_3	0.053	0.076	1092	K	WEST	+9.07	0.65	7.2		0.23		0.47	5.2		0.30		1.37	15.1	
			1115	KI	WEST	+8.94	0.49	5.5	4.5	0.18	0.14	0.53	5.9	7.5	0.35	0.44	0.92	10.3	13.2
			1092	K	EAST	+10.17	0.33	3.2		0.10		1.07	10.5		0.61		1.64	16.1	
			1115	KI	EAST	+9.17	0.18	2.0		0.06		0.76	8.3		0.48		1.03	11.2	

* GAGES LOCATED AT CENTER OF MEMBER + GAGES LOCATED AT END OF MEMBER

TABLE 4
SECONDARY STRESSES
SPAN 6
250'-0 THRU DRAW SPAN
(4 GAGES ON EACH MEMBER)



MEMBER	DEPTH / LENGTH HORIZONTAL AXIS (1-1)	DEPTH / LENGTH VERTICAL AXIS (2-2)	LOCOMOTIVE NUMBER	LOCOMOTIVE CLASS	LOCOMOTIVE DIRECTION	AVERAGE LIVE LOAD STATIC STRESS KIPS PER SQ. INCH	BENDING HORIZONTAL AXIS STRESS KIPS PER SQUARE INCH	HORIZONTAL AXIS PERCENT		HORIZONTAL AXIS DERIVED ECCENTRICITY INCHES		BENDING VERTICAL AXIS STRESS KIPS PER SQUARE INCH	VERTICAL AXIS PERCENT		VERTICAL AXIS DERIVED ECCENTRICITY INCHES		BOTH AXIS STRESS KIPS PER SQUARE INCH	BOTH AXIS PERCENT	
COLUMN	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
$U_6\ U_7$	0.043	0.060	1095	K	WEST	-6.40	0.28	4.4	6.7	0.17	0.26	0.04	0.6	0.9	0.04	0.06	0.56	8.8	10.0
			1094	K	WEST	-5.88	0.43	7.3		0.29		0.02	0.3		0.02		0.73	12.4	
			1094	K	EAST	-6.64	0.52	7.8		0.31		0.16	2.4		0.15		0.68	10.2	
			1094	K	EAST	-6.54	0.47	7.2		0.28		0.01	0.2		0.01		0.56	8.6	
$U_4\ U_5$	0.043	0.061	1092	K	WEST	+2.92	0.44	15.6	17.5	0.52	0.60	0.12	4.3	3.9	0.25	0.23	0.78	26.7	26.0
			1115	KI	WEST	+2.45	0.43	17.5		0.61		0.02	0.8		0.05		0.75	30.6	
			1095	K	EAST	+2.66	0.50	18.8		0.65		0.08	3.0		0.18		0.64	24.1	
			1095	K	EAST	+2.55	0.46	18.0		0.63		0.19	7.5		0.45		0.58	22.7	
$L_6\ L_7$	0.043	0.037	1095	K	WEST	+2.58	1.42	55.0	47.9	2.44	2.13	0.03	1.2	2.7	0.06	0.13	1.76	68.2	67.9
			1095	K	WEST	+2.51	1.28	51.0		2.26		0.09	3.6		0.17		2.06	82.1	
			1095	K	EAST	+3.48	1.44	41.4		1.84		0.02	0.6		0.03		1.98	56.9	
			1095	K	EAST	+3.56	1.57	44.1		1.96		0.19	5.3		0.26		2.29	64.4	
$U_6\ L_7$	0.0294	0.0255	1095	K	WEST	+5.22	0.57	10.9	5.9	0.44	0.24	0.03	0.6	1.0	0.03	0.06	0.81	15.5	9.3
			1094	K	WEST	+5.76	0.28	4.9		0.19		0.08	1.4		0.08		0.44	7.6	
			1094	K	EAST	+6.36	0.28	4.4		0.18		0.11	1.7		0.10		0.56	8.8	
			1094	K	EAST	+6.72	0.22	3.3		0.13		0.03	0.4		0.02		0.35	5.2	
$U_6\ L_6$	0.0403	0.035	1095	K	WEST	-3.53	0.09	2.6	3.5	0.12	0.16	0.33	9.4	5.3	0.45	0.26	0.36	10.2	9.5
			1095	K	WEST	-3.53	0.09	2.6		0.12		0.26	7.4		0.36		0.30	8.5	
			1095	K	EAST	-4.20	0.25	6.0		0.27		0.14	3.3		0.16		0.48	11.4	
			1095	K	EAST	-4.08	0.11	2.7		0.12		0.05	1.2		0.06		0.32	7.8	
$U_5\ L_6$	0.0294	0.0255	1095	K	WEST	+6.31	0.14	2.2	4.3	0.06	0.11	0.53	8.4	10.7	0.49	0.63	0.53	8.4	12.3
			1115	KI	WEST	+6.53	0.32	4.9		0.13		0.62	9.5		0.55		0.76	11.6	
			1137	KI	EAST	+6.43	0.32	5.0		0.13		0.74	11.5		0.67		0.88	13.7	
			1744	N.Y.C.	EAST	+6.13	0.31	5.1		0.13		0.83	13.5		0.79		0.94	15.3	
$U_5\ L_5$	0.0403	0.0572	1095	K	WEST	-4.51	0.07	1.6	3.9	0.06	0.14	0.24	5.3	3.6	0.32	0.22	0.89	19.7	14.1
			1115	KI	WEST	-4.64	0.11	2.4		0.08		0.11	2.4		0.14		0.77	16.6	
			1137	KI	EAST	-3.91	0.29	7.4		0.27		0.01	0.3		0.02		0.46	11.8	
			1137	KI	EAST	-4.89	0.20	4.1		0.15		0.31	6.3		0.38		0.41	8.4	

2. The simultaneous stresses in each member of both spans were measured with a gage on each corner. It was found that there was considerable variation between the stresses on the four corners, indicating bending stresses as well as direct stresses. A summary of these bending or secondary stresses is shown in Tables 3 and 4. The result of high secondary stresses in tension members is to make the member subject to fatigue failure. The result on compression members is to increase the eccentricity of the direct load at the center, thus lowering the buckling strength of the members.

In addition to the variation of stresses between the corners of the members, there is evidence that the stresses do not vary uniformly between the corners.

3. The variation in stresses, called semi-amplitudes, in the stringers, floor beams and floor beam posts were measured and the data indicated vibrational effects of greater magnitude than could be produced by the locomotive hammer blow alone. This vibrational effect has been termed "track and hammer blow effect" and the magnitude of this stress is shown in the upper right diagrams of Figs. 19 to 21, incl., for the 142-ft. deck span and Figs. 34 and 35 for the 250-ft. draw span. The track effect stress, which is the resulting stress after the unmagnified hammer blow stress has been subtracted from the total, is shown in the center diagrams. The concentrated load or blow at the center of the span to produce this track effect stress is shown in the lower diagrams of the above figures.

The stresses resulting from the track condition were about the same as those found in tests on other short span bridges.

4. The semi-amplitude of stress in the individual members of the trusses was also measured and the data indicated greater vibrational effects in some members than would be predicated by the 1947 precise rating rules. It is evident that the vibrational effects are not the same in each member of a truss and that these effects cannot be properly analyzed from center deflection readings alone. A summary of these vibrational effects in the chord and web members, in terms of the magnification of the locomotive hammer blow stresses, is shown in Figs. 17 and 18 for the 142-ft. deck span and Figs. 36 and 37 for the 250-ft. draw span. The magnification of the locomotive hammer blow, as specified in the 1947 AREA precise rating rules is also shown on these diagrams for the 142-ft. deck span.

5. The increase in maximum stresses under the locomotives at various speeds over that recorded at a speed of approximately 10 mph. has been termed "total impact."

The total impacts recorded in the stringers, floor beams and floor beam posts, in percent of the recorded static stresses, are shown in the left diagrams of Figs. 19 to 21, incl., for the 142-ft. deck span and Figs. 34 and 35 for the 250-ft. draw span. As shown in these diagrams, the total impacts were greater than those specified by the 1947 precise rating rules but were appreciably lower than the 1947 design specification.

The total impacts recorded in the individual chord and web members are shown in the left diagrams of Figs. 9 to 16 incl., for the 142-ft. deck span and Figs. 22 to 31 for the 250-ft. draw span. It can be seen that there is considerable variation in the total impacts in the individual members of these spans, which is apparently due to the variation in the magnification of the locomotive hammer blow stresses.

A summary of the total impacts in the chord and web members of these spans is shown in Figs. 36 to 39, incl., as well as those predicated by the 1947 AREA design specification and precise rating rules. The total impacts in the end posts and chord members of the 142-ft. deck span exceeded the 1947 AREA design specification by a small amount, while those in the web members were appreciably larger than the design specification. The total impacts exceeded the rating rules allowance by a large amount.

The total impacts in the end posts and chord members of the 250-ft. draw span were about the same as those recorded in the end posts and chord members of the 142-ft. deck span. The total impacts in the web members of the two spans were also about the same, being appreciably greater than those in the end posts and chord members.

6. The carrying capacity or rating of the individual members, in terms of Cooper loading, was determined for the Toledo Terminal Railroad, but as this information is of no general interest, only typical rating computations are shown in this report.

2. Foreword

The bridge impact tests analyzed in this report were conducted at the request of the Toledo Terminal Railroad and the salaries and expenses of the personnel operating the instruments were borne entirely by the railroad. The tests were made in the fall of 1944 and were carried out under the general direction of G. M. Magee, research engineer, Engineering Division, Association of American Railroads. The conduct of the tests, analysis of data and preparation of the report were in charge of E. J. Ruble, structural engineer, research staff, AAR.

The bridge tested, see Figs. 1, 2 and 3, was built in 1901 and was designed for Cooper E–40 loading. The Toledo Terminal Railroad has a speed restriction of 10 mph. over the bridge and previously did not allow any locomotive whose axle weight exceeded 58,000 lb. to cross the bridge. Because the various railroads using this bridge have in recent years frequently asked permission to operate heavier classes of power, the Toledo Terminal requested the research staff of the AAR to determine the carrying capacity of the bridge by means of strain gage measurements.

The general procedure in making the tests on this bridge was first to determine the stresses in the individual members under those locomotives permitted to cross the bridge at 10 mph. Since the stresses were not exceedingly high at 10 mph. it was decided to measure the stresses in the same members at various locomotive speeds up to about 45 mph. in order to determine the impact values resulting from such speeds.

The general procedure in making the tests under the trains at higher speeds was to have one of the regular trains with a class K or K1 locomotive stop about a mile from the bridge, uncouple all the cars except the first four back of the tender and then proceed to the bridge. The locomotive and cars would then cross the bridge at various speeds ranging from 10 mph. to 43 mph. It was possible to secure about 10 test runs in this manner with a train delay of less than one hour.

A total of 57 runs were secured for the special tests on the 142-ft. span (Span 7) by delaying 6 trains, while 38 runs were obtained on the 250-ft. draw span (Span 6) by delaying 3 trains. A total of 178 test runs were made on the bridge including all regular trains.

Arrangements were made with the operating officers of the Toledo Terminal Railroad to secure the weights of the tender and of the first four cars following the tender for all the trains crossing over the bridge during the tests. It was necessary to know these weights so that the recorded stresses could be compared with the calculated strains. Telephone service was provided between the bridge and the dispatcher by placing a telephone in the test building.

3. Instruments

The instruments used in these tests were of the electrical type and were fully described in the Proceedings, Vol. 42, 1941. The gages used were of the electromagnetic type having a 2-in. gage length. Two 12-element oscillographs were used so 24 simultaneous stresses were recorded for each test run of the locomotive.

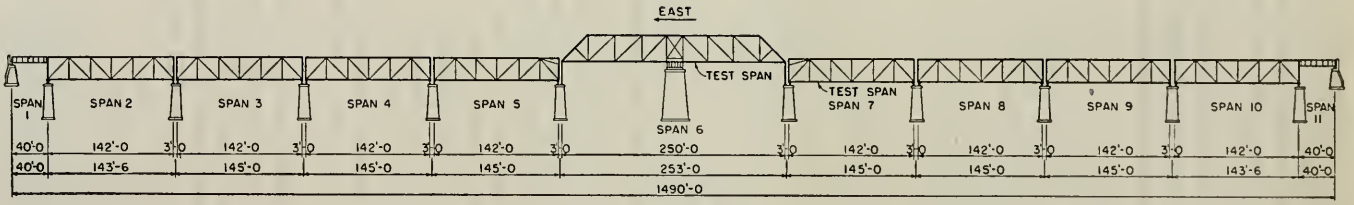


FIG. 1
TOLEDO TERMINAL RR. BRIDGE TESTS
MAUMEE RIVER BRIDGE
TOLEDO, OHIO
LOCATION OF TEST SPANS

Fig. 2.—General View of the Test Bridge.

Fig. 3.—A View from One End of the Test Bridge.

The relative position of each locomotive wheel with respect to the panel points U_1 and U_5 was indicated by the two solenoid marker units in each oscillograph through the use of a spring-type switch on the wheel position markers located at the panel points.

The speed of the locomotive was readily obtained from the oscillograph film by determining the elapsed time for the first wheel to travel the known distance between panel points U_1 and U_5 (see typical strain record, Fig. 8). With the locomotive speed known, the position of any wheel at any time, such as the time of maximum stress in any member, could readily be ascertained.

The strain gages were calibrated individually before the test runs were started and after completing the test runs. The average values obtained for each gage were used in arriving at the stress factors or the amount of stress in the steel per inch of deflection of the light trace on the film for that particular gage. In general, a 1-in. deflection of the light trace on the film indicated a strain in the steel of 0.0008 in. for the 2-in. gage length, which is equivalent to a stress of 12,000 psi., assuming a modulus of elasticity of 30,000,000 psi.

No effort was made to measure the vertical or lateral deflections.

4. Test Spans and Location of Instruments

The bridge tested is located in Toledo, Ohio, and spans the Maumee River. The bridge consists of one 250-ft. through truss draw span, eight 142-ft. deck truss spans and two 40-ft. deck plate girder spans (see Fig. 1). Representative members of the 250-ft. draw span (Span 6) and one 142-ft. deck span (Span 7) were tested as shown in Figs. 4 and 5.

In order to measure the stresses resulting from the bending of the members as well as those due to the direct loads, it was decided to place four gages on each member for the tests under the regular trains. The members of both trusses were tested to determine the effects of any track eccentricity as well as differences in locomotive loading. The location of the gages on the various members tested is shown in Figs. 4 and 5.

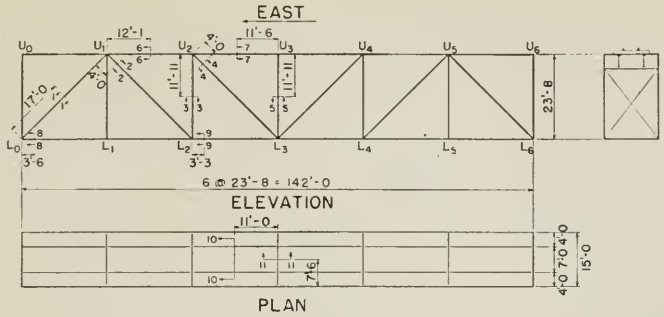
As previously mentioned, only 24 gages were available, so only 3 members of each truss were tested at one time. As soon as a sufficient number of runs, usually eight or ten, had been secured for the one location of the gages, called a series, the gages were changed to three more members for the next series.

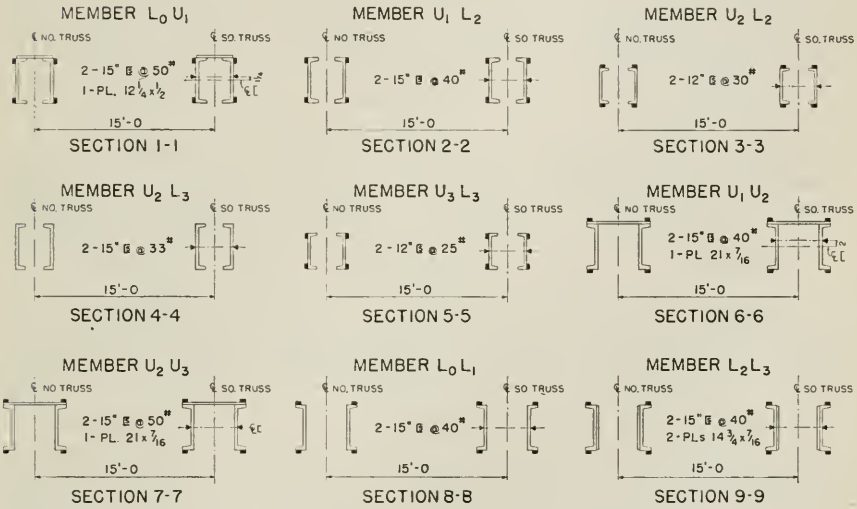
In order to properly analyze the data secured on the 250-ft. draw span it was necessary to determine the live load end reactions at L_0 and L_9. Accordingly, 2 gages were placed at the horizontal neutral axis of members L_0 U_1 and U_8 L_0 of both trusses for the tests under the regular trains. The vertical component of the average total stress in these members is equivalent to the vertical reaction.

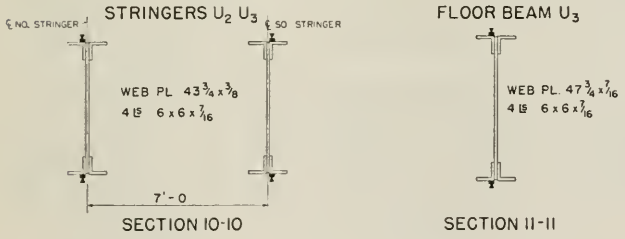
After the completion of the tests under the regular trains at slow speeds, two gages were placed on each member of the south truss as shown by the triangular symbol on Figs. 4 and 5 for the tests under the locomotives at higher speeds. By placing the gages in this manner, the simultaneous strains in 12 different members of one truss were recorded.

5. Test Trains

The stresses were recorded under locomotive and cars of the Chesapeake & Ohio, the Baltimore & Ohio, the Pere Marquette, the New York Central and the Toledo Terminal. However, since the special test runs were made with the Chesapeake & Ohio locomotives, only the data obtained under these locomotives were completely analyzed for this report. The necessary information regarding these locomotives, such as axle weights, axle spacing, nominal wheel diameters, and all information required to calculate



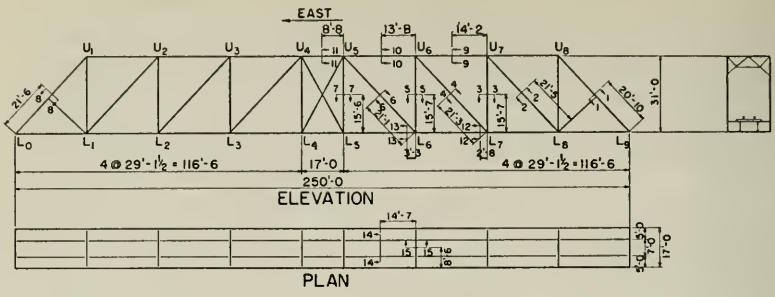


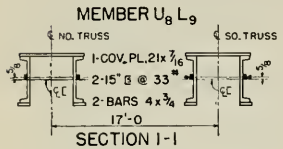


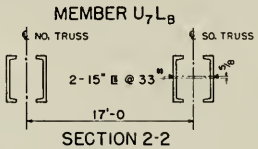
SYMBOL:

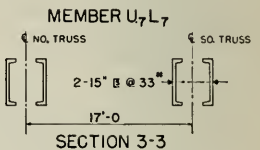
- ▬ LOCATION OF STRAIN GAGES FOR READINGS UNDER REGULAR TRAINS AT LOW SPEEDS
- ▼ LOCATION OF STRAIN GAGES FOR READINGS UNDER SPECIAL TEST TRAINS AT HIGHER SPEEDS

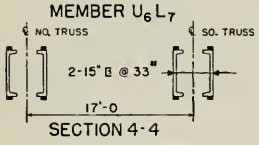
FIG 4
TOLEDO TERMINAL RR BRIDGE TESTS
SPAN 7
142'-0 DECK TRUSS SPAN
OPEN TIMBER DECK
LOCATION OF GAGES

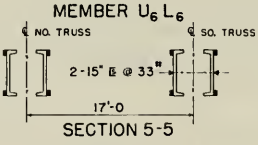


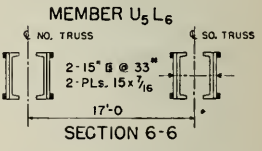


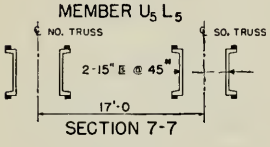


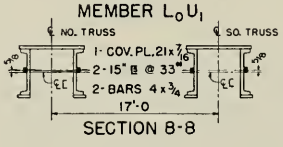


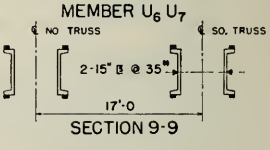


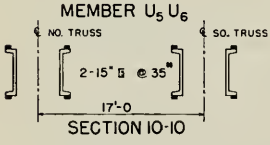


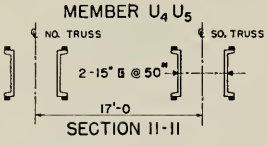


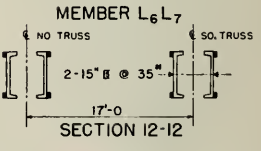


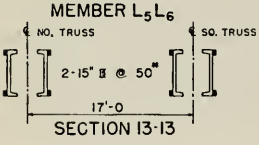


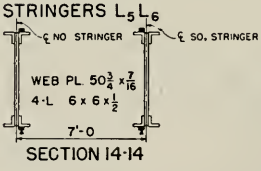


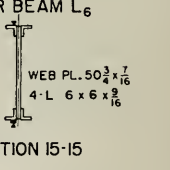












SYMBOL

- LOCATION OF STRAIN GAGES FOR READINGS UNDER REGULAR TRAINS AT LOW SPEEDS
- ▼ LOCATION OF STRAIN GAGES FOR READINGS UNDER SPECIAL TEST TRAINS AT HIGHER SPEEDS

FIG. 5
TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
LOCATION OF GAGES

the components and resultant unbalanced weights on the driving wheels was furnished by the mechanical department of the Chesapeake & Ohio Railway.

The steam locomotives used in these tests for the special test runs were of the two-cylinder type, the right pin leading by 90 deg. and with the eccentric crank leading. There were no diesel or electric locomotives operating over the bridge.

Steam Locomotive—Mikado Type 2–8–2 (class K)

The locomotives of this class are used in freight service and all general data regarding them are shown in Fig. 6. The weights and spacing of the car axles are those used in the special test runs, which are about the same as those of the regular scheduled trains.

The total weight of these locomotives without tender, is 322,480 lb. The tenders, with 9000 gal. of water and 17 tons of coal weigh 173,000 lb. The rating of locomotive, tender and cars for the chord and web test members of the 142-ft. span, in terms of Cooper loading, varied from E–39.0 to E–51.6. The rating for center bending moment on the stringers was E–57.9 and E–58.4 on the floor beams and floom beam posts.

These locomotives have an average reciprocating unbalance per side per ton of locomotive weight in working order of 6.58 lb. and an average reciprocating compensation of 30 percent.

The drivers are all straight balanced with considerable underbalance on the main driver. The calculated hammer blow stress on the gross section in member U_2 U_3 of the 142-ft. span at one revolution per second is 18.9 psi. The calculated hammer blow stress on the gross section in the stringers at one revolution per second is 45.2 psi., 43.5 psi. in the floor beam and 31.1 psi. in the floor beam post.

Steam Locomotive—Mikado Type 2–8–2 (class K1)

The locomotives of this class are also used in freight service and all general data regarding them are shown in Fig. 7. The weights and spacing of the car axles are those used in the special test runs, which are about the same as those of the regular scheduled trains.

The total weight of these locomotives, without tender, is 323,000 lb. The tenders, with 9000 gal. of water and 15 tons of coal weight 168,280 lb. The rating of locomotive, tender and cars for the chord and web test members of the 142-ft. span, in terms of Cooper loading, varied from E–37.8 to E–48.8. The rating for center bending moment on the stringers is E–56.6 and E–57.5 on the floor beams and floor beam posts.

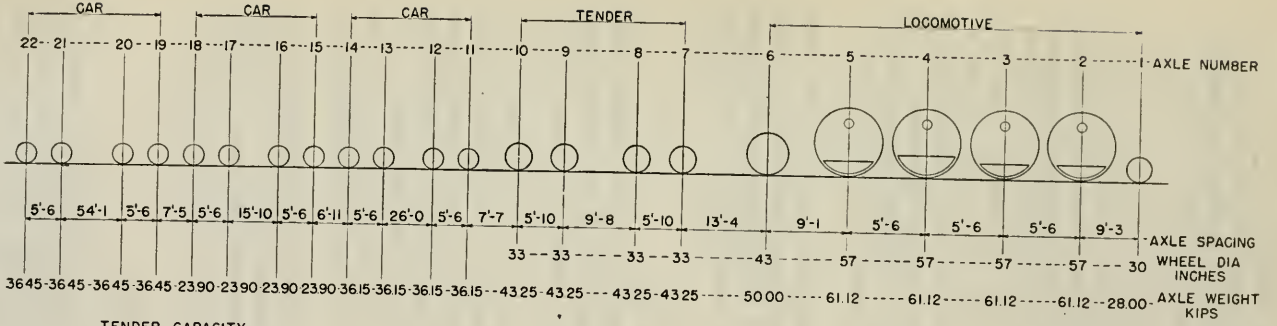
These locomotives have an average reciprocating unbalance per side per ton of locomotive weight in working order of 6.91 lb. and an average reciprocating compensation of 26 percent.

The drivers are all straight balanced with considerable underbalance on the main drivers. The calculated hammer blow gross stress in member U_2 U_3 of the 142-ft. span at one revolution per second is 15.7 psi. The calculated hammer blow gross stress in the stringers at one revolution per second is 38.9 psi., 33.4 psi. in the floor beam and 23.9 psi. in the floor beam posts.

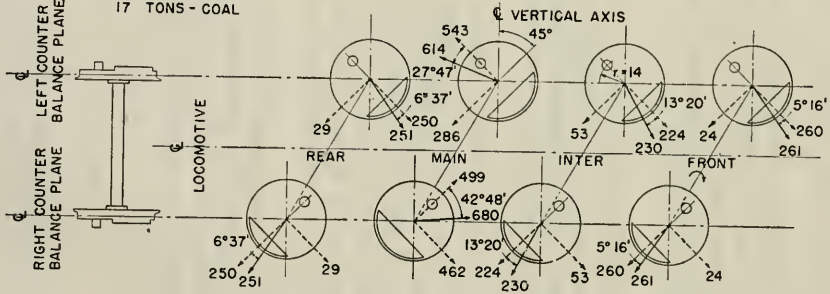
6. Analysis of Field Records

Test Records

The test records were photographed on sensitized paper 10 in. wide and 200 ft. long. Each record was marked with the name of the railroad, bridge number and date. The oscillograph and run number, which is photographed on the record after each run, refers to the log of test runs which shows the engine number, direction, approximate speed, type of train and all other necessary information regarding the test run.



TENDER CAPACITY
9,000 GALS. - WATER
17 TONS - COAL



COMPONENTS AND RESULTANT UNBALANCED WEIGHT IN POUNDS

HAMMER BLOW AT ONE REVOLUTION PER SECOND

	RIGHT SIDE	LEFT SIDE
FRONT DRIVER	373	373
INTER. DRIVER	329	329
MAIN DRIVER	973	878
REAR DRIVER	359	359

RECIPROCATING COMPENSATION

	RIGHT SIDE	LEFT SIDE
FRONT DRIVER	284	284
INTER. DRIVER	277	277
MAIN DRIVER	-213	-81
REAR DRIVER	279	279
TOTAL	627	759
AVERAGE	693	

RECIPROCATING WEIGHTS AVERAGE FOR ONE SIDE

PISTON AND ROD	944
CROSSHEAD	760
UNION LINK	26
MAIN ROD	591
TOTAL	2,321

TOTAL WEIGHT OF LOCOMOTIVE IN WORKING ORDER - POUNDS 495,480

AVERAGE RECIPROCATING WEIGHT PER SIDE - POUNDS 2,321

AVERAGE RECIPROCATING COMPENSATION PER SIDE - POUNDS 693

AVERAGE RECIPROCATING UNBALANCE PER SIDE - POUNDS 1,628

AVERAGE RECIPROCATING UNBALANCE PER SIDE PER TON OF LOCOMOTIVE WEIGHT IN WORKING ORDER - POUNDS $= \frac{1,628}{247.7} = 6.58$

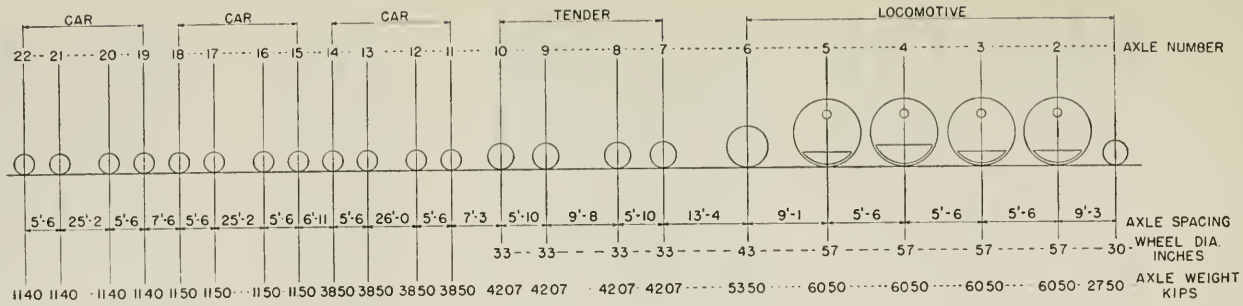
AVERAGE RECIPROCATING COMPENSATION $= \frac{693}{2,321} = 0.30$

H.B. $= \frac{W}{g} \cdot r \cdot \omega^2$

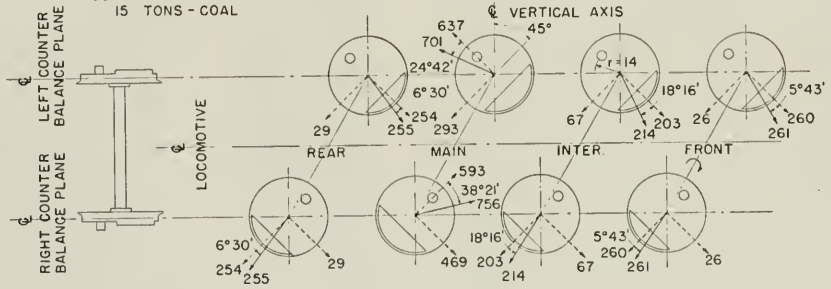
H.B. @ l.r.p.s. $= \frac{W}{32.2} \cdot 1.17 \cdot 6.28^2 = 1.43W$

H.B. - HAMMER BLOW
W - RESULTANT UNBALANCED WEIGHT
r - CRANK PIN RADIUS
ω - ANGULAR VELOCITY IN RADIANS

FIG. 6
TOLEDO TERMINAL RAILROAD
BRIDGE TESTS
TEST TRAIN DATA
LOCOMOTIVE-MIKADO TYPE 2-8-2
C.&O. CLASS K.



TENDER CAPACITY
9000 GALS - WATER
15 TONS - COAL



COMPONENTS AND RESULTANT UNBALANCED WEIGHT IN POUNDS

HAMMER BLOW AT ONE REVOLUTION PER SECOND

	RIGHT SIDE	LEFT SIDE
FRONT DRIVER	373	373
INTER. DRIVER	306	306
MAIN DRIVER	1,081	1,002
REAR DRIVER	365	365

RECIPROCATING COMPENSATION

	RIGHT SIDE	LEFT SIDE
FRONT DRIVER	286	286
INTER. DRIVER	270	270
MAIN DRIVER	-300	-168
REAR DRIVER	283	283
TOTAL	539	671
AVERAGE	605	

RECIPROCATING WEIGHTS AVERAGE FOR ONE SIDE

PISTON AND ROD	944
CROSSHEAD	737
UNION LINK	34
MAIN ROD	585
TOTAL	2,300

TOTAL WEIGHT OF LOCOMOTIVE IN WORKING ORDER - POUNDS 491,280

AVERAGE RECIPROCATING WEIGHT PER SIDE - POUNDS 2,300

AVERAGE RECIPROCATING COMPENSATION PER SIDE - POUNDS 605

AVERAGE RECIPROCATING UNBALANCE PER SIDE - POUNDS 1,695

AVERAGE RECIPROCATING UNBALANCE PER SIDE PER TON OF LOCOMOTIVE WEIGHT IN WORKING ORDER - POUNDS $= \frac{1,695}{245.6} = 6.91$

AVERAGE RECIPROCATING COMPENSATION ..... $= \frac{605}{2,300} = 0.26$

$HB = \frac{W}{g} \cdot r \cdot \omega^2$

$HB @ 1 r.p.s. = \frac{W}{32.2} \cdot 1.17 \cdot 6.28^2 = 1.43W$

HB - HAMMER BLOW
W - RESULTANT UNBALANCED WEIGHT
r - CRANK PIN RADIUS
ω - ANGULAR VELOCITY IN RADIANS

FIG. 7

TOLEDO TERMINAL RAILROAD
BRIDGE TESTS
TEST TRAIN DATA
LOCOMOTIVE-MIKADO TYPE 2-8-2
C. & O. CLASS K-1.

Since it would have made this report too voluminous to include reproductions of all the test film, only a typical record is included as shown in Fig. 8. The films are now on file in the Engineering Division offices, AAR, at Chicago.

Reading of Records

For an analysis of the records it was first necessary to find the base lines representing zero stress. As shown on the typical strain record (see Fig. 8), the first 2 or 3 in. of the record were taken before the locomotive reached the span; the record was continued with the locomotive on the span and for 2 or 3 in. after the locomotive and cars were off the span. Base lines, representing zero stress were then drawn from one side of the light trace for all the gages connecting the two "no load" parts of the record. Light pencil lines were drawn on the records indicating the upper and lower enevelope curves through the peaks of the oscillations. The mean stress curve was then indicated in pencil midway between the upper and lower envelope curves. The mean stress curves for the slow locomotive speeds represent the static stress at the gage position for the different positions of the locomotive as it passes over the span. Hence the average of the greatest mean stresses for the slow speed runs of 10 mph. and under was used in arriving at the recorded static stresses.

The semi-amplitude of stress or the difference between the upper envelope curve and the mean stress curve (see Fig. 8), is produced by irregularities of the track and the effect of the locomotive hammer blow. At slow speeds of about one revolution per second of the locomotive drivers, the effect of the hammer blow in producing oscillations is negligible so that the semi-amplitude of stress is almost entirely due to the track condition. At higher speeds the effect of the hammer blow in producing oscillations in the structure increases rapidly. At or near synchronous speed, and at lower speeds, the oscillations keep building up until they reach a maximum, which usually occurs at the time of maximum mean stress. At speeds higher than the synchronous speed, maximum oscillations always occur some time before the time of maximum mean stress. It has been interesting to note from the records that the frequency of these oscillations coincides with the speed of the locomotive drivers in revolutions per second.

Stress Corrections

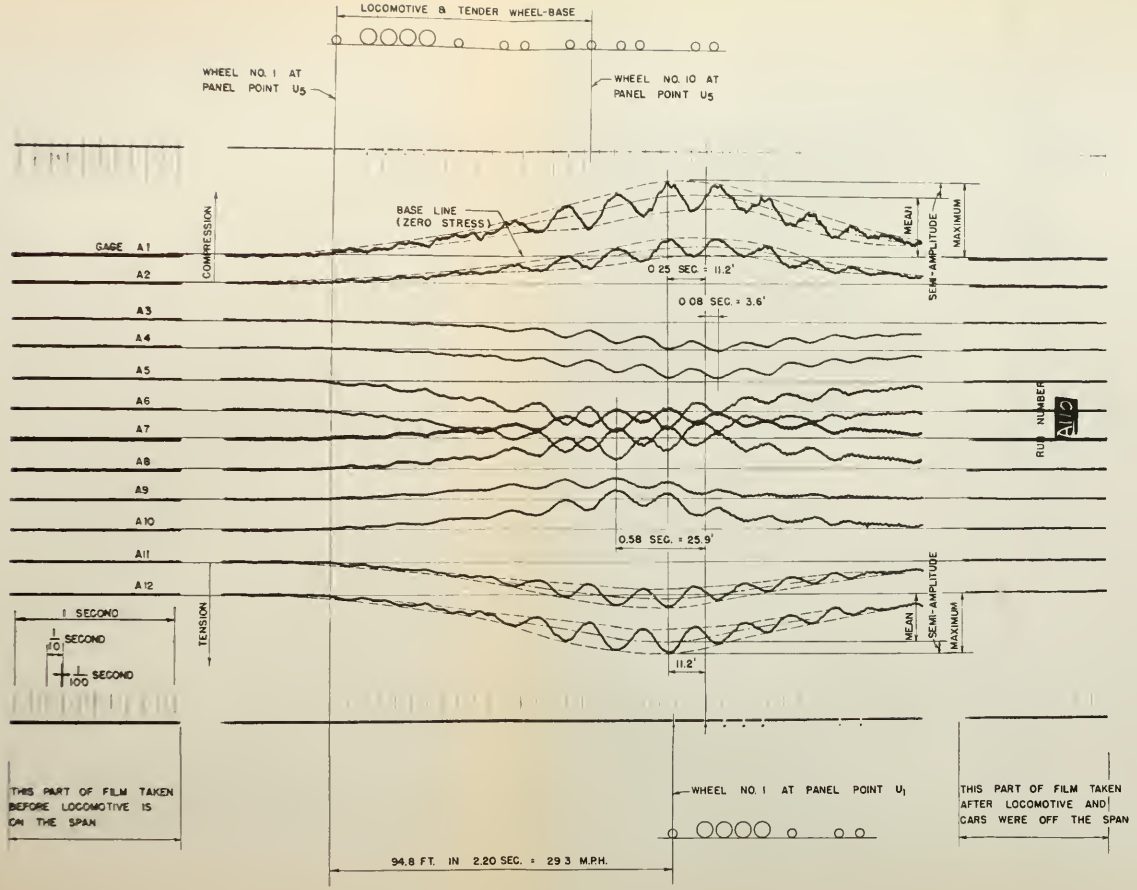
The center of gravity of the "air gap" on the magnetic strain gage being 0.44 in. from the base, the strains were correspondingly recorded on a plane 0.44 in. from the surface of the steel. The stresses recorded in the stringers and floor beams were corrected by assuming that the stress is proportional to the distance from the neutral axis. The only correction required to the stresses recorded in the chord and web members was that resulting from the bending of the members.

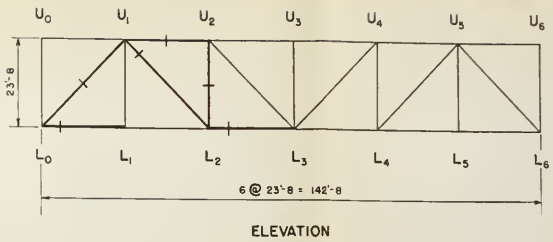
Tabulation of Stresses

The mean, semi-amplitude and maximum galvanometer deflections were scaled from the oscillograph records and tabulated. The stresses were then determined for each gage by multiplying the galvanometer deflection by the stress factor determined from the calibration of the gages. The locomotive's speed and the position on the bridge of the first driver for the stress tabulated are also shown on the tabulation sheets.

Tables were then prepared for each test member showing the average mean, semi-amplitude and maximum stress in the member. The average stress, obtained by averaging the four or two gages on the member, represents the direct stress. The stresses were tabulated according to locomotive classes and in order of speeds.

A
B
C





ELEVATION

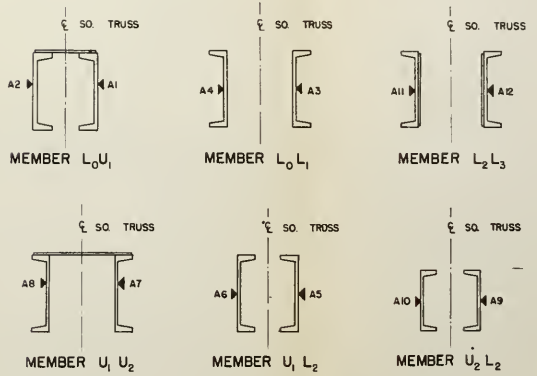


FIG. 8

TOLEDO TERMINAL RAILROAD
BRIDGE TESTS

TYPICAL STRAIN RECORD

SPAN 7 - 142 FT. DECK TRUSS

MIKADO 2-8-2
(C & O CLASS "K")

The secondary stresses, as found in this bridge, are based on the greatest stress found at the corner of the members while the impacts are based on the average stresses.

The tables containing all the data taken from the film and entitled "Tabulation of Recorded Stresses" and "Analysis of Strain Gage Readings" are on file in the Engineering Division offices, AAR.

7. Impact and Other Effects as Found From the Test Data

The data, as taken from the oscillograph records and summarized in the previously mentioned tables, were analyzed for the particular purpose of segregating and determining the magnitude of the various dynamic and other effects of the live load. The results of this study are as follows:

Static Stresses

The recorded static direct stresses for each test member for the various locomotives and cars at slow speeds were determined in the following manner:

1. With four gages on the corresponding member of each truss the greatest simultaneous mean stresses recorded at slow speeds by the four gages were averaged to secure the direct stress in the symmetrical members. When the members were unsymmetrical, such as the top chord member having a cover plate, it was necessary to correct the average stress to determine the direct stress at the neutral axis of the member. The direct stresses recorded in the north and south trusses were then averaged to secure the recorded static stress. The direct stress recorded in the corresponding members of both trusses was about the same, indicating that there was very little track eccentricity or rolling effect at the slow speeds of 10 mph. or under.

2. With two gages located on the neutral axis of the members of the south truss, the greatest mean stresses recorded by the two gages were averaged to secure the direct stress in the member, which was also taken as the recorded static stress in the member for the slow speed runs.

3. The recorded static stress in the stringers was secured by averaging the greatest mean stresses recorded by the two gages on the lower flanges.

4. The recorded static stress in the floor beams was the greatest mean stress recorded at slow speeds by the one gage on the lower flange.

The static direct stress in the test members under the various locomotives and cars was calculated for comparison with the recorded static stresses. The exact position of the locomotive which produced the maximum recorded stress was secured from the test records and this same locomotive position was used for the calculated stresses. The amount of coal and water used out of the tender at the time of the test run was subtracted from the tender weights and the calculated stresses are based upon the revised tender weights. The exact car weights were obtained from the train consist, while the length of the cars was secured from the test record.

As previously mentioned, the gages were left on the end posts of the 250-ft. draw span for all the runs, so that the live load end reactions could be determined from the vertical component of the stress in these members. However, since the recorded stress in the end post U_8 U_9 was only 12 percent greater (see Table 2, Col. 9) than the calculated stress based on a continuous two span structure of constant moment of inertia, it was felt that the calculated stresses in the other members of the 250-ft. span could be based on the same assumption with a fair degree of accuracy. Accordingly, the

stresses were calculated in the test members for the corresponding position of the locomotive and cars as those recorded.

The comparison of the recorded and calculated live load static stresses and the stress factors, or the ratio of the recorded to the calculated stresses, for the individual test runs is shown in column 8 of Tables 1 and 2, while the average stress factor is shown in column 9. It can be seen that there is considerable variation between the recorded and calculated stresses, especially on the 142-ft. deck span. It appears from the results shown in Table 1 that the stringers have a marked influence on the static stresses in the chords. For example, the recorded static stress in member U_2 U_3 of the 142-ft. deck span varied from 71 to 80 percent of the calculated static stress with an average of 75 percent. With the stringers acting as part of the compression chord, there would be a shift in the neutral axis of this chord, and the effective depth of the truss would be somewhat smaller than the distance between the upper and lower chords. The decrease in the effective depth of the truss could be the cause of the high stress factor in member L_2 L_3 of the 142-ft. span (see Table 1) where it varied from 1.23 to 1.34, with an average of 1.31.

The only explanation that can be offered for the difference in stress factors between those obtained with four gages on the member and those with two gages on the same member is that the stress did not vary uniformly over the section. It was shown by tests on other bridges, as in the case of the oscillator tests, where the strains in test members were measured with Berry gages, that the stress does not vary uniformly over the section.

The low stress factors in the stringers of both the 142-ft. span and the 250-ft. draw span are about the same as those found in previous tests of short beam spaces, see Proceedings, Vol. 46, 1945. The higher stress factors in the floor beams could be due to the stiffness of these members.

Secondary Stresses and Eccentricity

The data secured with four gages on the members afforded an opportunity for the study of the secondary stresses and derived eccentricity in the various members, and the summary of this study for the 142-ft. deck span and the 250-ft. draw span is shown in Tables 3 and 4. It should be kept in mind that the tests were planned to determine the rating of the bridge and not the maximum secondary stresses. For example, the gages were generally placed at the center of the compression members instead of the ends, as it was felt the allowed compressive stress should be based on the center eccentricity.

The average live load static stresses shown in column 7 of Tables 3 and 4 were determined in the same manner as those shown in column 6 of Tables 1 and 2. However, the values in Tables 3 and 4 are for the members of one truss only.

The bending stresses about the horizontal axis shown in column 8 of Tables 3 and 4 were determined by subtracting the average live load static stress from the average of the two gages on either the top or bottom of the member, whichever was the largest. The bending stresses about the vertical axis shown in column 13 were determined by subtracting the static stress from the average of the two gages on one side of the member. The bending stresses shown in column 18 were determined by subtracting the static stress from the maximum recorded value on one of the four corners. The values shown in columns 9, 14 and 19 of these tables are the percentages of the static stresses which would produce the bending stresses.

The derived eccentricities shown in columns 11 and 16 of Tables 3 and 4 were determined by solving for e_{1-1} and e_{2-2} in the following equations:

$$f^b_{1-1} = \frac{P \times e_{1-1} \times c_{1-1}}{I_{1-1}} \quad \ldots\ldots (1)$$

$$f^b_{2-2} = \frac{P \times e_{2-2} \times c_{2-2}}{I_{2-2}} \quad \ldots\ldots (2)$$

where

f^b_{1-1} = the bending stress about the horizontal axis.
P = the average static stress times the area of the members.
e_{1-1} = the eccentricity about the horizontal neutral axis.
c_{1-1} = the distance from the horizontal neutral axis to the extreme fiber.
I_{1-1} = the moment of inertia about the horizontal neutral axis.
f^b_{2-2} = the bending stress about the vertical axis.
e_{2-2} = the eccentricity about the vertical neutral axis.
c_{2-2} = the distance from the vertical neutral axis to the extreme fiber.
I_{2-2} = the moment of inertia about the vertical neutral axis.

It should be pointed out that there was considerable variation between the derived eccentricities as determined from the test results and those that would have been estimated from the relation of the neutral axis of the member and the working line of the truss. For example, the horizontal neutral axis of the unsymmetrical member L_0 U_1 of the 142-ft. deck span is 0.04 in. below the working line of the truss while the vertical neutral axis is on the working line. The average eccentricity, about the horizontal axis, as determined from the test results (see column 12, Table 3) was 0.41 in. instead of the 0.04 in. while the average eccentricity about the vertical axis amounted to 0.89 in. where normally one would expect no eccentricity except that due to inherent crookedness.

Track and Hammer Blow Effect

The most important source of vertical oscillations in the longer span railroad bridges such as these is the periodic disturbing force of the unbalance in the drivers of the steam locomotives. The recorded dynamic effects as found in this report are due to both track effect and hammer blow effect. It is quite possible that in some cases the condition of the track would tend to counteract the oscillations due to the hammer blow. On the other hand, the oscillations due to the track conditions might be additive to the oscillations caused by the hammer blow. Since for these tests, there is no way to determine the separate effects, the only alternative is to report their combined effect.

The theory of vibrations as pertaining to impact in railway bridges of simple span has been fully discussed in the Proceedings, Vol. 37, 1936, page 761, and this theory has been followed in determining the natural frequency, dynamic magnifiers and damping factors for the steam locomotives on the 142-ft. deck span. Unfortunately, no theory has as yet been developed for the determination of the damping factors of a continuous span under forced vibration, as in the case of a steam locomotive on the 250-ft. draw span, so the only alternative at this time was to show the recorded semi-amplitudes and derived dynamic magnifiers. An analytical method of determining the natural period of vibration of a continuous span under uniform load has been developed by L. E. Vandegrift in a bulletin published by the Engineering Experiment Station of the Ohio State University. However, no effort was made to determine the loaded frequency of this span.

If a detailed study of the impact in continuous spans or draw spans is ever undertaken, then it will be necessary to develop a mathematical analysis for the determination of the damping factors.

142-Ft. Deck Span—Chord and Web Members

The stress semi-amplitudes, as read from the oscillograph film and tabulated in the previously mentioned tables for the test members of the 142-ft. span, are shown in the upper right diagrams of Figs. 9 to 16, incl. The values shown are the averages obtained with two gages on each member.

The dynamic magnifiers or the ratio of the measured semi-amplitudes to the calculated stresses in the member due to the unmagnified hammer blow for the test members of the 142-ft. span are shown in the lower right diagrams of Figs. 9 to 16, incl. The method used in determining the dynamic magnifiers will now be shown by a typical example. The maximum semi-amplitude recorded in member $U_2\ U_3$ was 1.58 kips per sq. in. and occurred at a speed of 2.99 rps. under a class K locomotive. The calculated hammer blow stress at one revolution per second in this member is 0.0252 kips per sq. in. and by correcting this theoretical stress by the stress factor of 0.75, as found in Table 1 for this member, the actual hammer blow stress at one revolution per second is found to be 0.0189 kips per sq. in. The unmagnified hammer blow stress for a locomotive speed of 2.99 rps. becomes equal to $0.0189 \times 2.99^2 = 0.168$ kips. per sq. in. The dynamic magnifier for this run then equals $1.58 \div 0.169 = 9.35$.

The calculated values which might be expected and which are based on damping factors as recommended in the 1947 AREA precise rating rules for steel bridges, are expressed by the solid curves. It can be seen that the recorded values are well above the calculated values. It is quite evident that the damping qualities of the span were smaller than those assumed in the rating rules for a span of similar length.

The discrepancy between the recorded values for the dynamic magnifiers and those predicated by the 1947 AREA precise rating rules is believed due to the following:

1. The values as determined by the 1947 AREA precise rating rules are based on deflections which are the summations of the deformations in all the members of the span. This method assumes that the maximum semi-amplitudes of stress resulting from the locomotive hammer blow occur simultaneously in all the members of the span and that the hammer blows are magnified the same amount for each member.

2. The values as determined from the test results are based on the maximum semi-amplitudes of stress in the individual test members of the span. It can be seen from the typical test record, Fig. 8, that the maximum semi-amplitudes of stress did not occur simultaneously in all the test members. It was shown in the report of the oscillator tests, that the hammer blows are not magnified the same amount for all the members of a truss.

The dynamic magnifiers as recorded in the end posts and chord members have been plotted in the summary diagram, Fig. 17, while those recorded in the web members are shown in Fig. 18.

It is apparent from the values plotted in these diagrams that a loaded frequency of $n = 2.90$ vibrations per second would be about an average value for the end posts and chord members as well as the web members. The loaded frequency n of the 1947 AREA precise rating rules equals 3.09 vibrations per second and was determined from the calculated loaded deflection, as no actual deflections were recorded.

The damping factor and the damping constant for this span were determined from the following equations:

(Text continued on page 710)

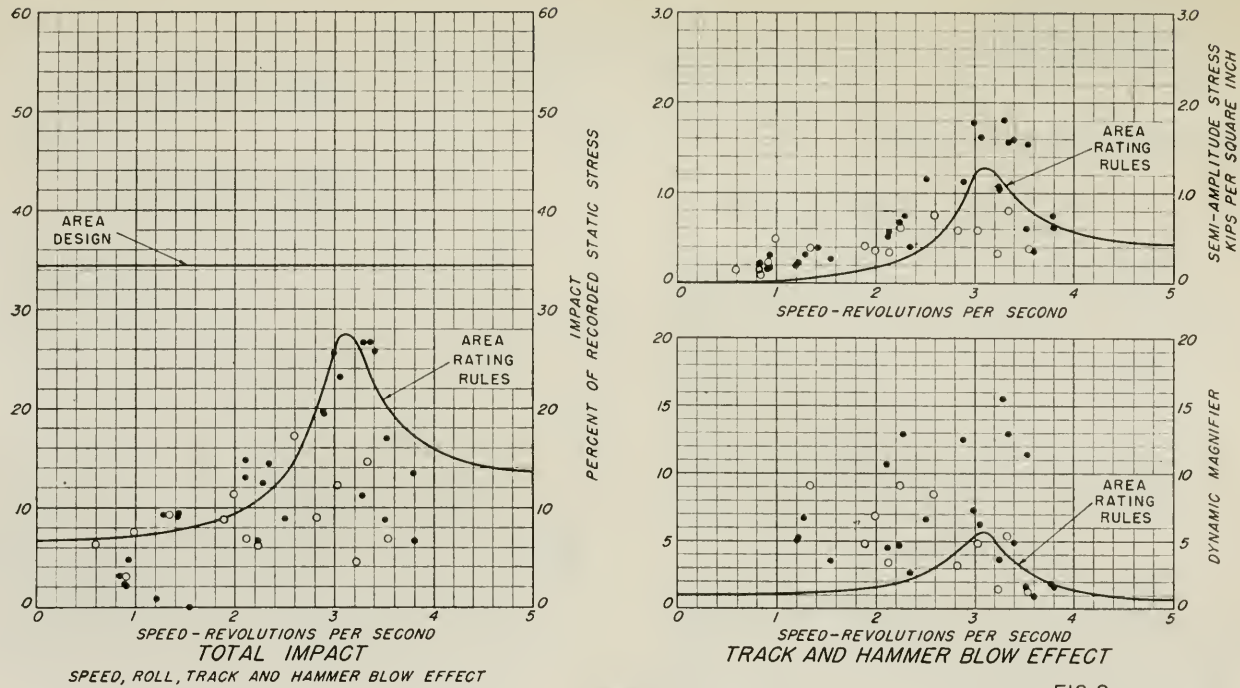
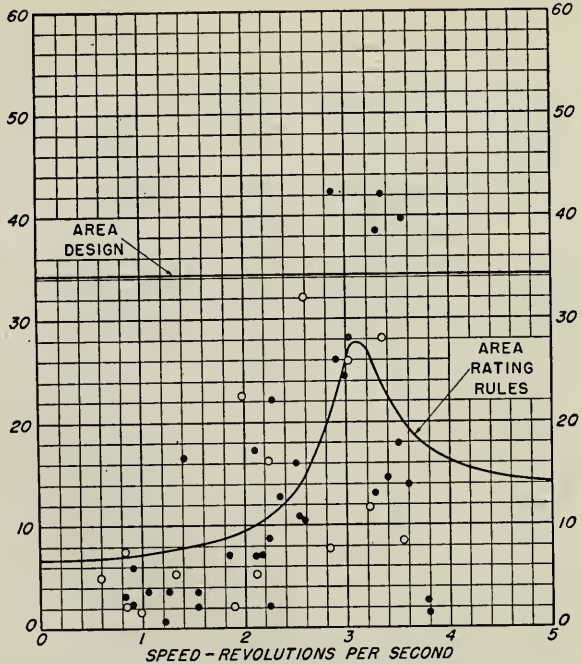
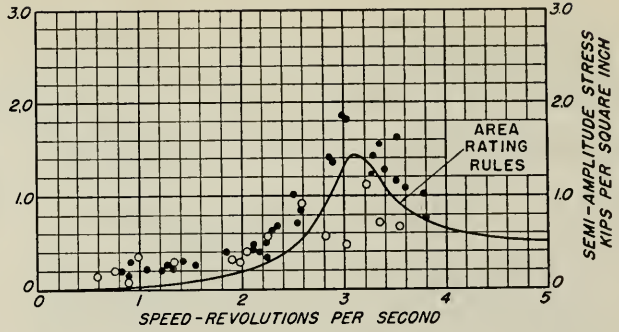
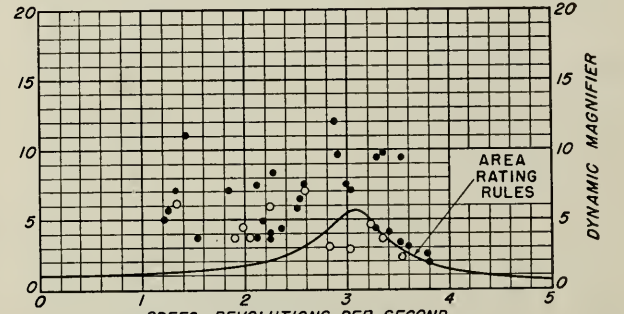


FIG. 9
TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 7
142'-0 DECK TRUSS SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER L_0-U_1



TOTAL IMPACT
SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT





TRACK AND HAMMER BLOW EFFECT

SYMBOL:
- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K1"

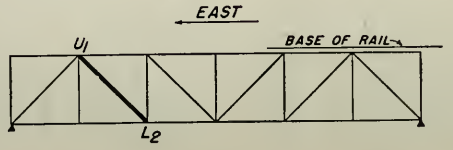


FIG. 10
TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 7
142'-0 DECK TRUSS SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER U_1 - L_2

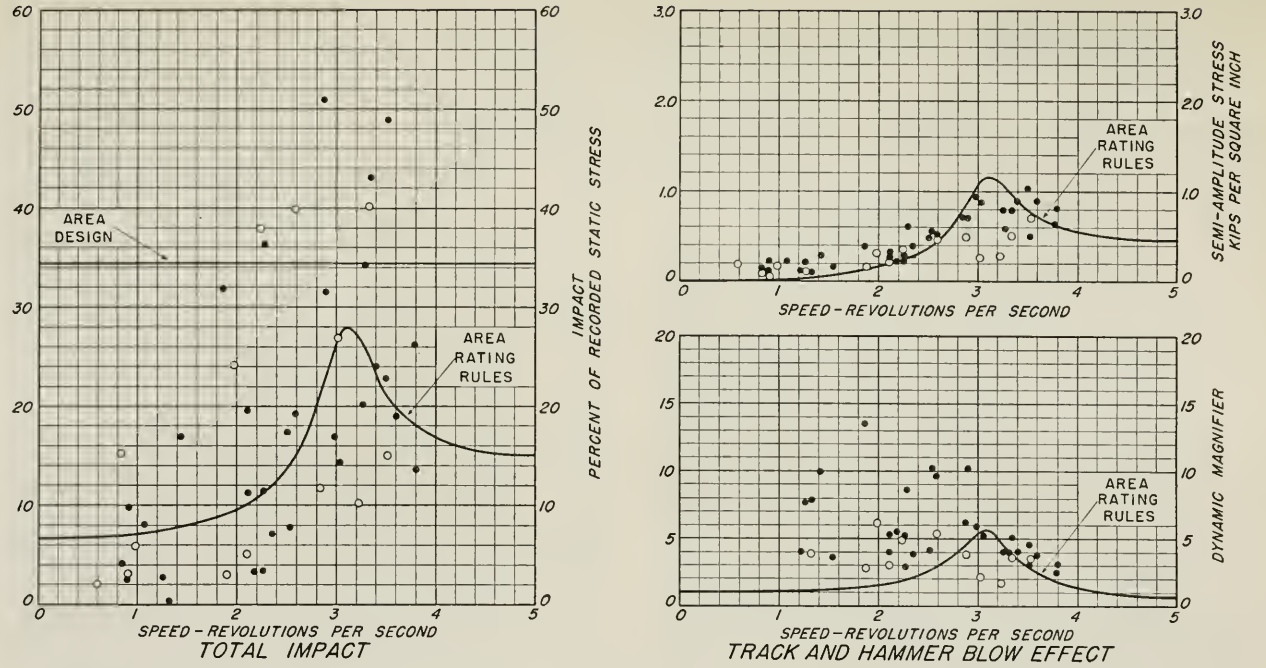


FIG. 11
TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 7
142'-0 DECK TRUSS SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER U_2-L_3

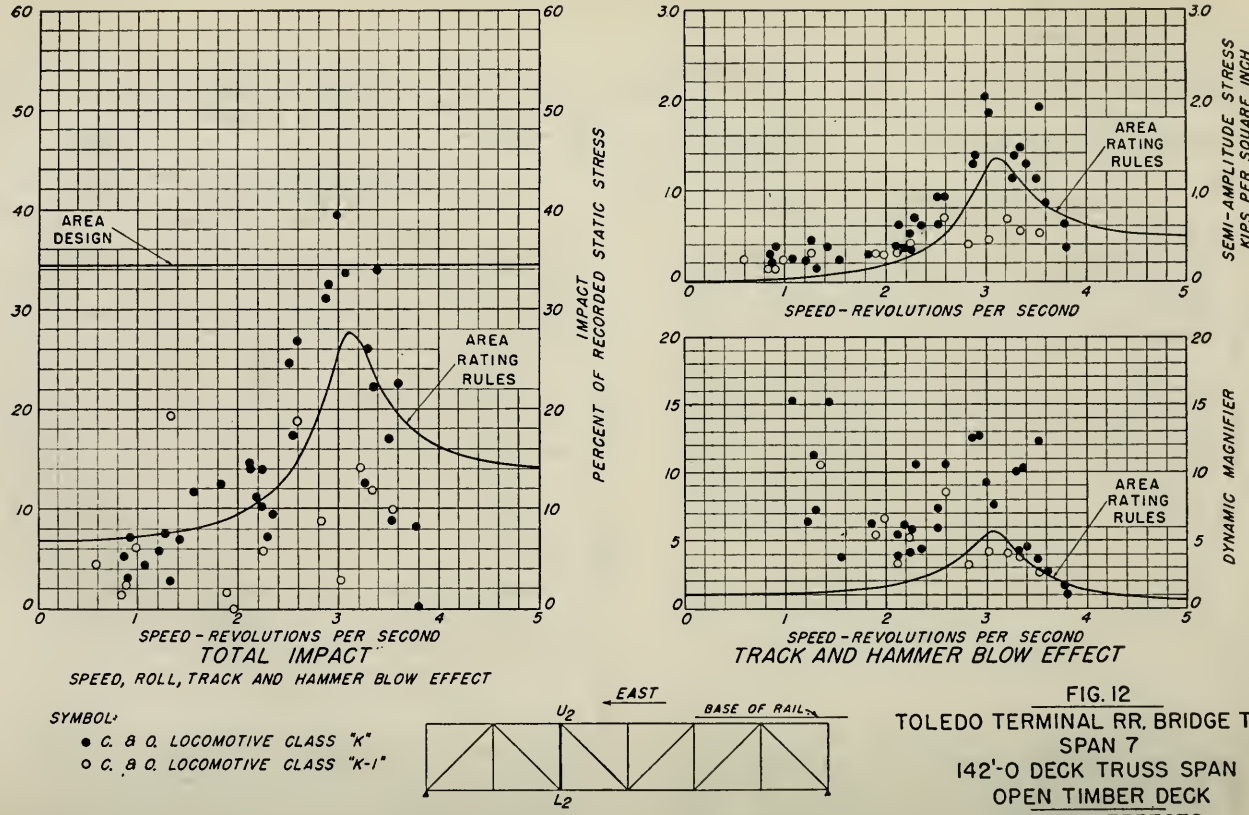
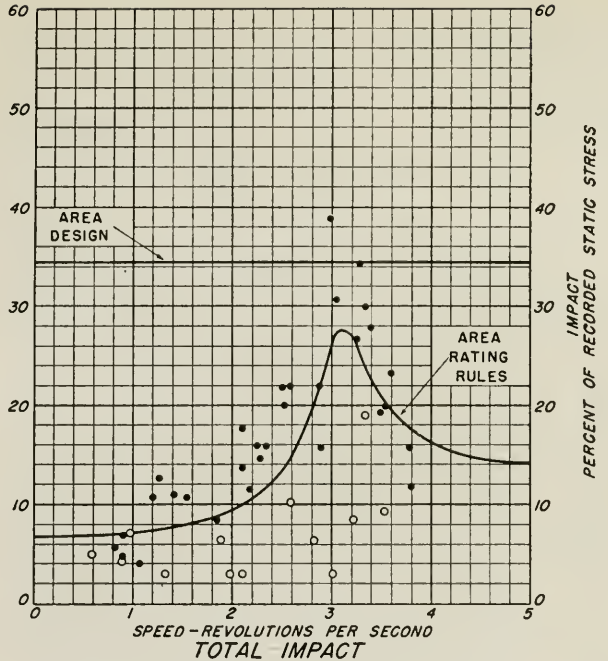
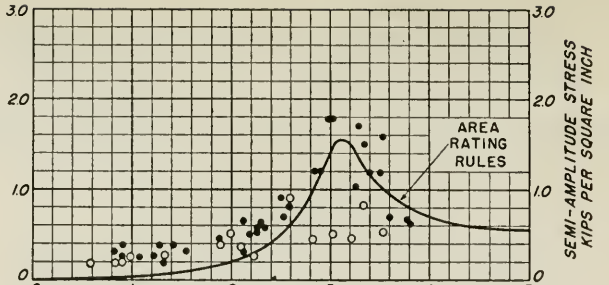


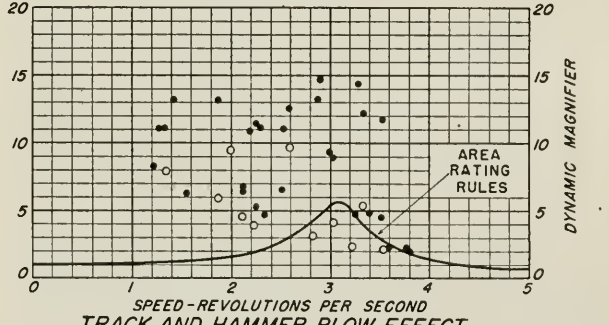
FIG. 12
TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 7
142'-0 DECK TRUSS SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER U_2-L_2



TOTAL IMPACT

SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT





TRACK AND HAMMER BLOW EFFECT

SYMBOL:

- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K-1"

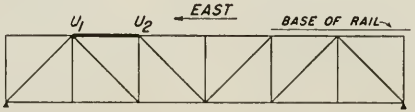
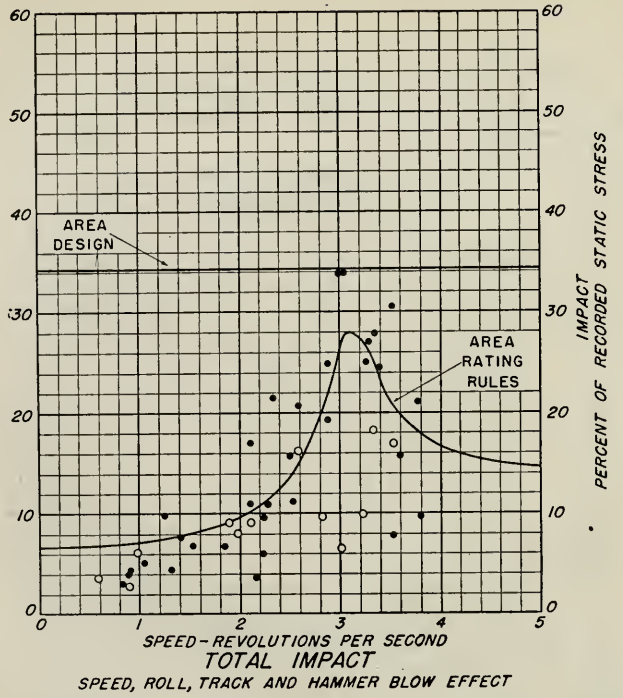
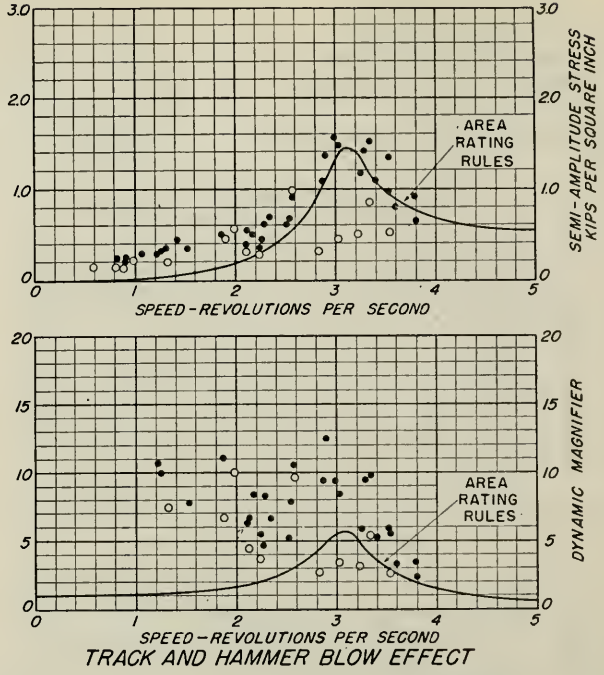


FIG. 13

TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 7
142'-0 DECK TRUSS SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER U_1-U_2





SYMBOL:
- ● C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K1"

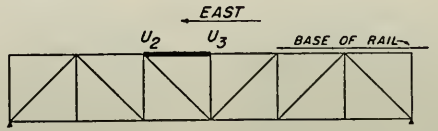
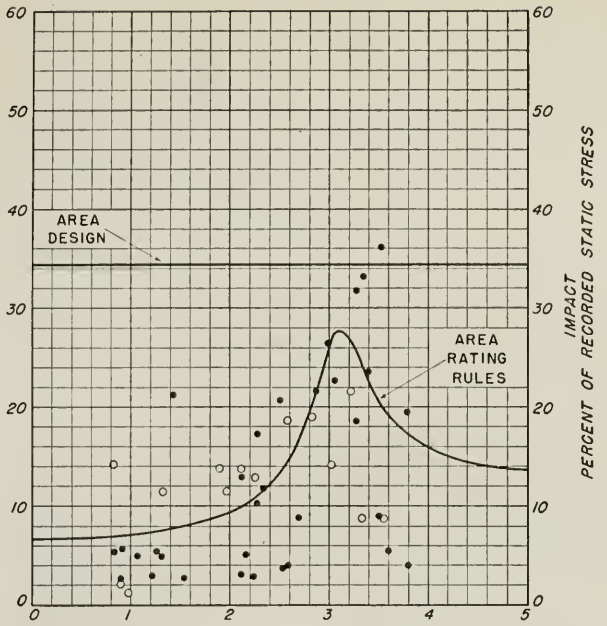
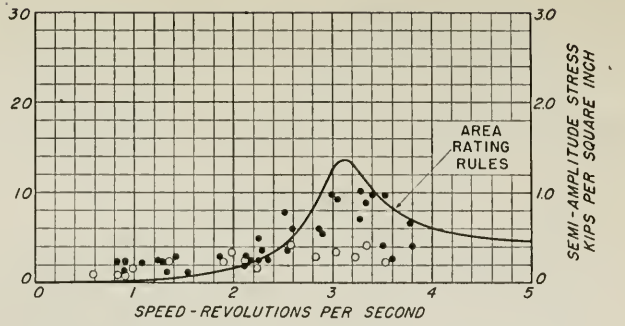


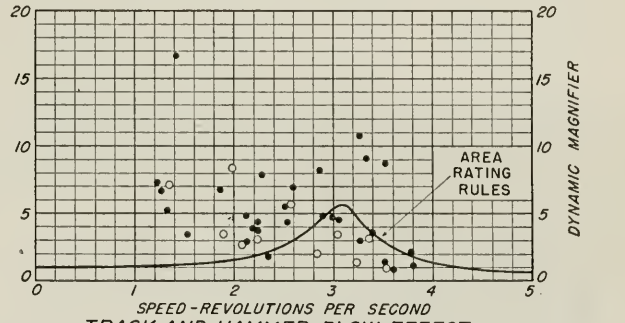
FIG. 14
TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 7
142'-0 DECK TRUSS SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER U_2-U_3



TOTAL IMPACT

SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT





TRACK AND HAMMER BLOW EFFECT

SYMBOL:

- ● C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K1"

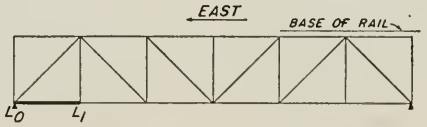
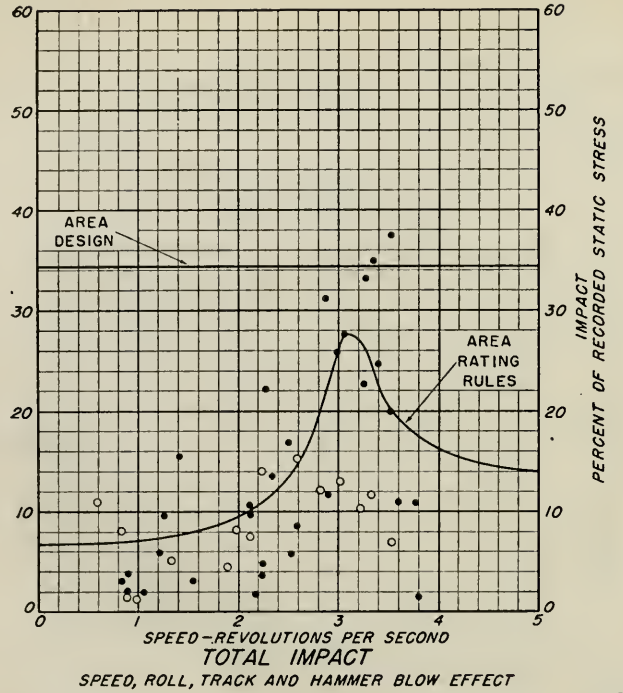
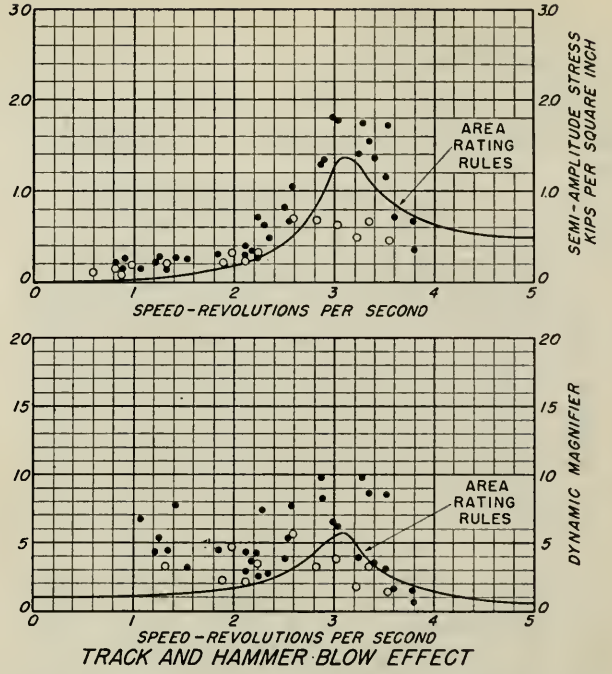


FIG. 15

TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 7
142'-0 DECK TRUSS SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER L_0-L_1





SYMBOL:
- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K1"

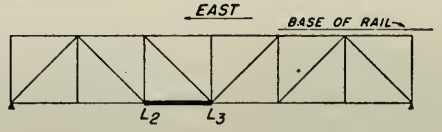
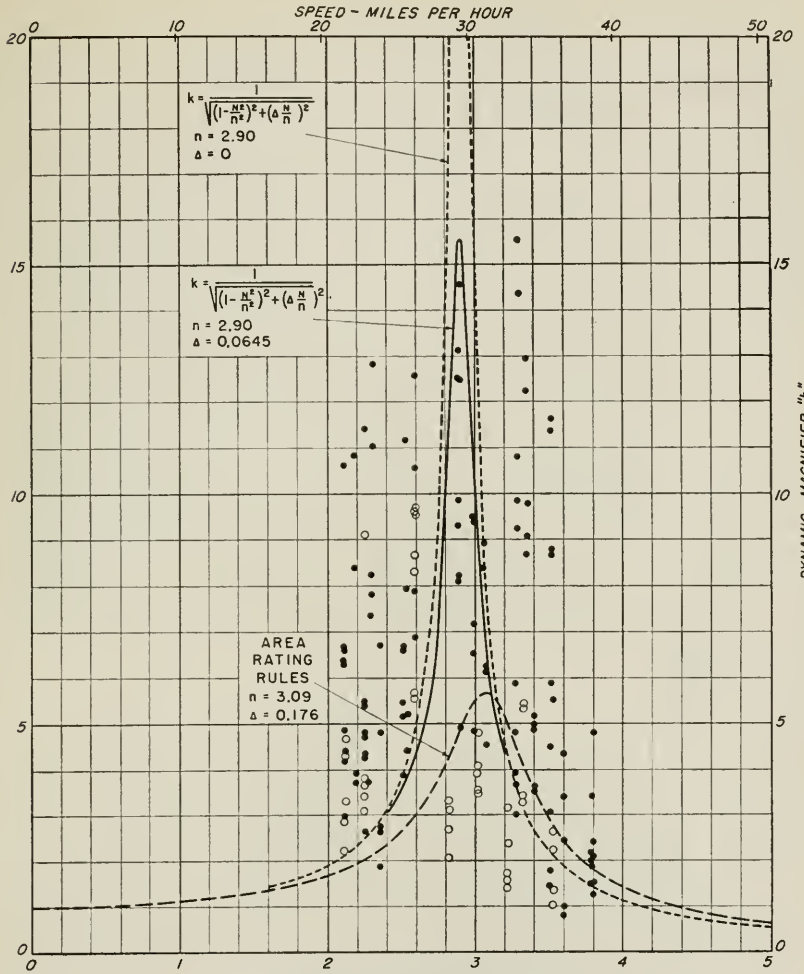


FIG. 16
TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 7
142'-0 DECK TRUSS SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER L_2-L_3



TRACK AND HAMMER BLOW EFFECT

SYMBOL:
- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "KH"

DERIVED TEST DATA:
LOADED FREQUENCY - n = 2.90 VIB. PER SEC.
DAMPING CONSTANT - p = 0.0111
DAMPING FACTOR - Δ = 0.0645

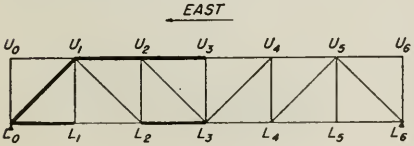
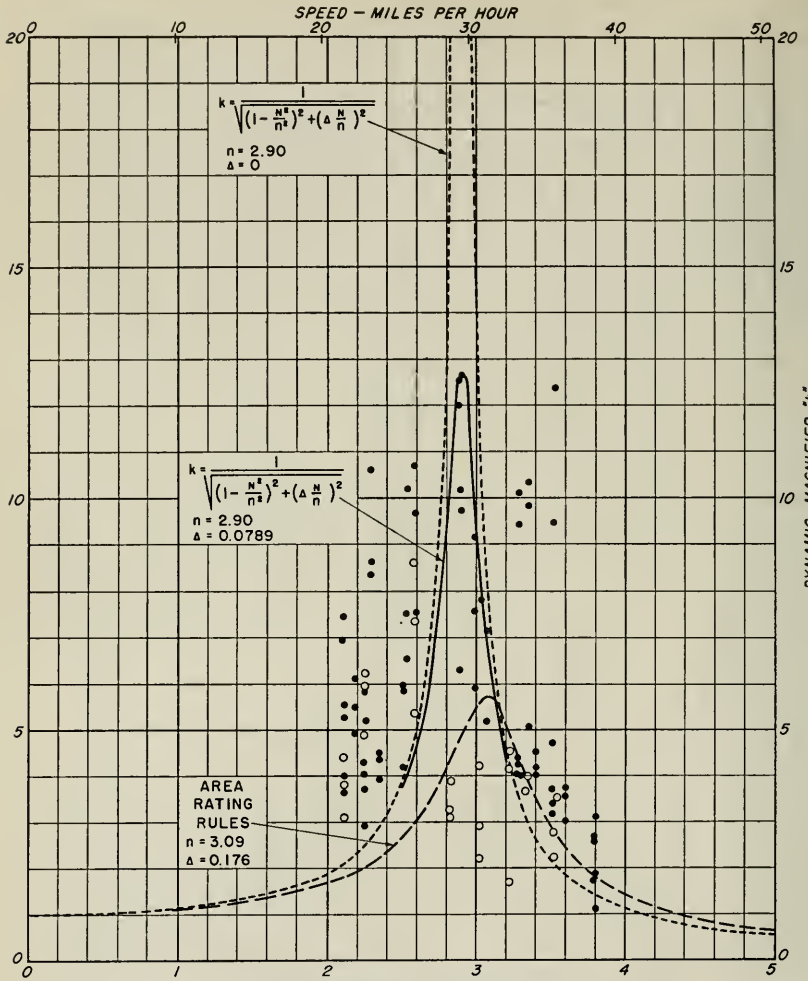


FIG. 17
TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 7
142'-0 DECK TRUSS SPAN
OPEN TIMBER DECK
SUMMARY OF TRACK AND
HAMMER BLOW EFFECTS
END POST AND CHORD MEMBERS



TRACK AND HAMMER BLOW EFFECT

SYMBOL:
- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K-1"

DERIVED TEST DATA:
LOADED FREQUENCY – n=2.90 VIB. PER SEC.
DAMPING CONSTANT – p=0.0136
DAMPING FACTOR – Δ=0.0789

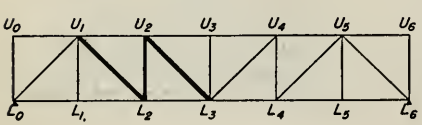
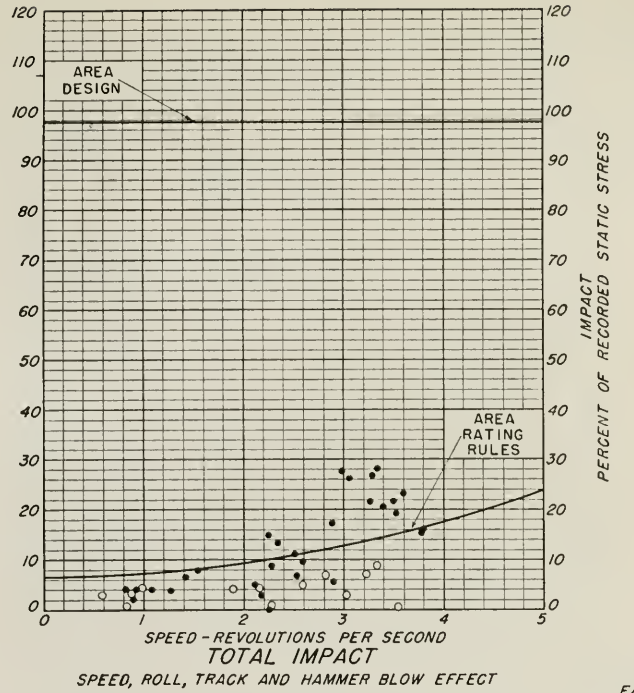
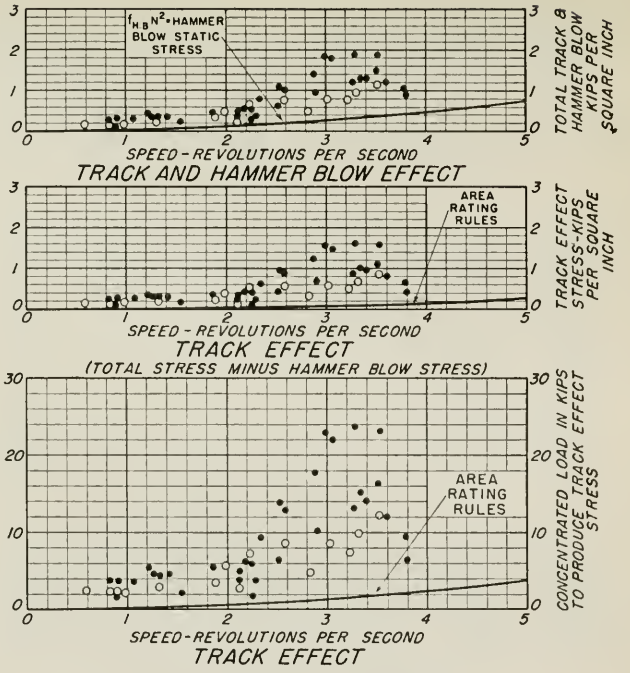


FIG. 18
TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 7
142'-0 DECK TRUSS SPAN
OPEN TIMBER DECK
SUMMARY OF TRACK AND HAMMER BLOW EFFECTS
WEB MEMBERS



SYMBOL:
- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K1"


$f_{HB}N^2$ = HAMMER BLOW STATIC STRESS
TOTAL TRACK & HAMMER BLOW KIPS PER SQUARE INCH
SPEED - REVOLUTIONS PER SECOND
TRACK AND HAMMER BLOW EFFECT
AREA RATING RULES
TRACK EFFECT STRESS-KIPS PER SQUARE INCH
SPEED - REVOLUTIONS PER SECOND
TRACK EFFECT
(TOTAL STRESS MINUS HAMMER BLOW STRESS)
AREA RATING RULES
CONCENTRATED LOAD IN KIPS TO PRODUCE TRACK EFFECT STRESS
SPEED-REVOLUTIONS PER SECOND
TRACK EFFECT

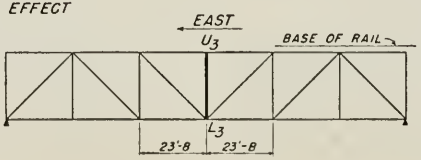


FIG. 19
TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 7
142'-0 DECK TRUSS SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER U_3-L_3

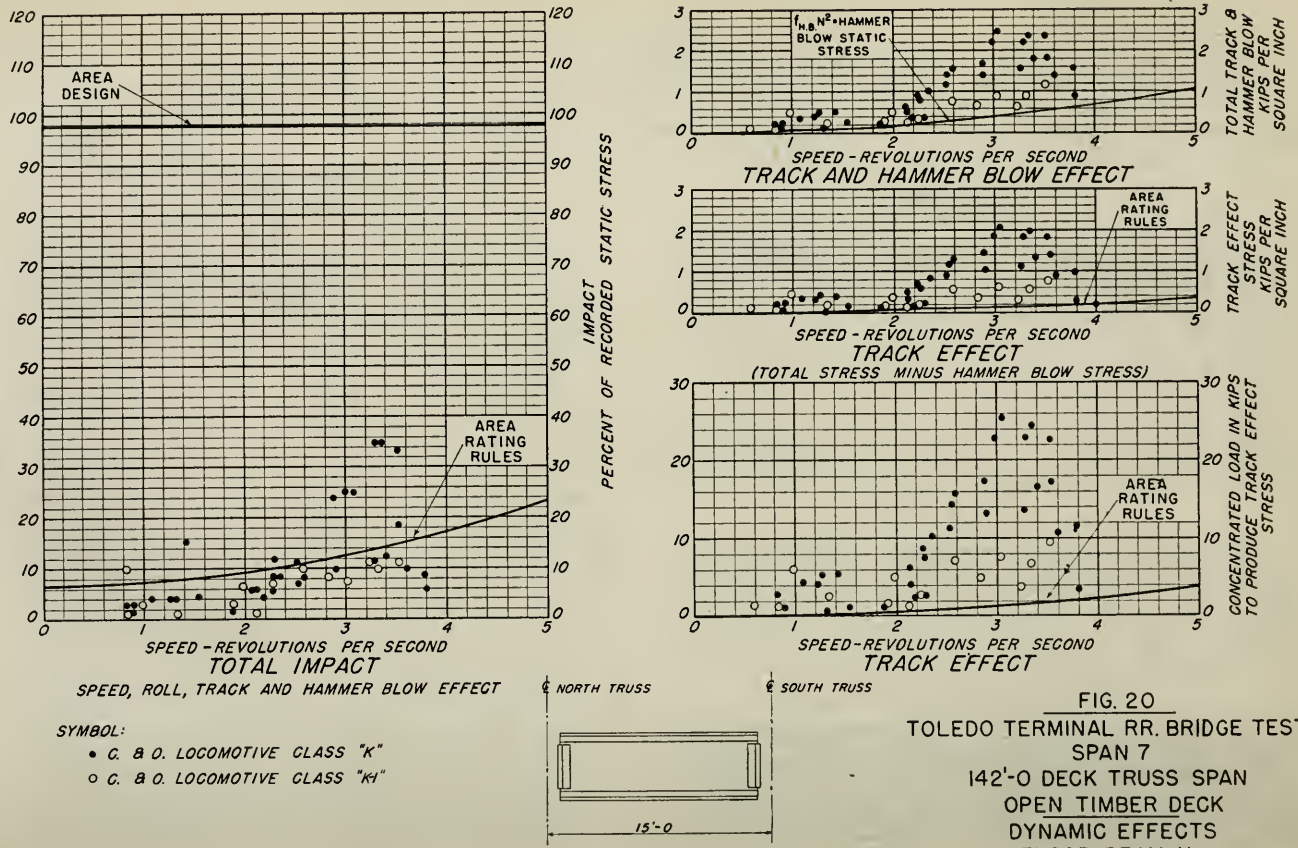

AREA DESIGN
AREA RATING RULES
PERCENT OF RECORDED STATIC STRESS
IMPACT
SPEED - REVOLUTIONS PER SECOND
TOTAL IMPACT
SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT
SYMBOL:
• C. & O. LOCOMOTIVE CLASS "K"
○ C. & O. LOCOMOTIVE CLASS "K1"
$f_{H.B.}N^2$ • HAMMER BLOW STATIC STRESS
TOTAL TRACK & HAMMER BLOW KIPS PER SQUARE INCH
SPEED - REVOLUTIONS PER SECOND
TRACK AND HAMMER BLOW EFFECT
AREA RATING RULES
TRACK EFFECT STRESS KIPS PER SQUARE INCH
SPEED - REVOLUTIONS PER SECOND
TRACK EFFECT
(TOTAL STRESS MINUS HAMMER BLOW STRESS)
AREA RATING RULES
CONCENTRATED LOAD IN KIPS TO PRODUCE TRACK EFFECT STRESS
SPEED-REVOLUTIONS PER SECOND
TRACK EFFECT
℄ NORTH TRUSS
℄ SOUTH TRUSS
15'-0

FIG. 20

TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 7
142'-0 DECK TRUSS SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
FLOOR BEAM U_3

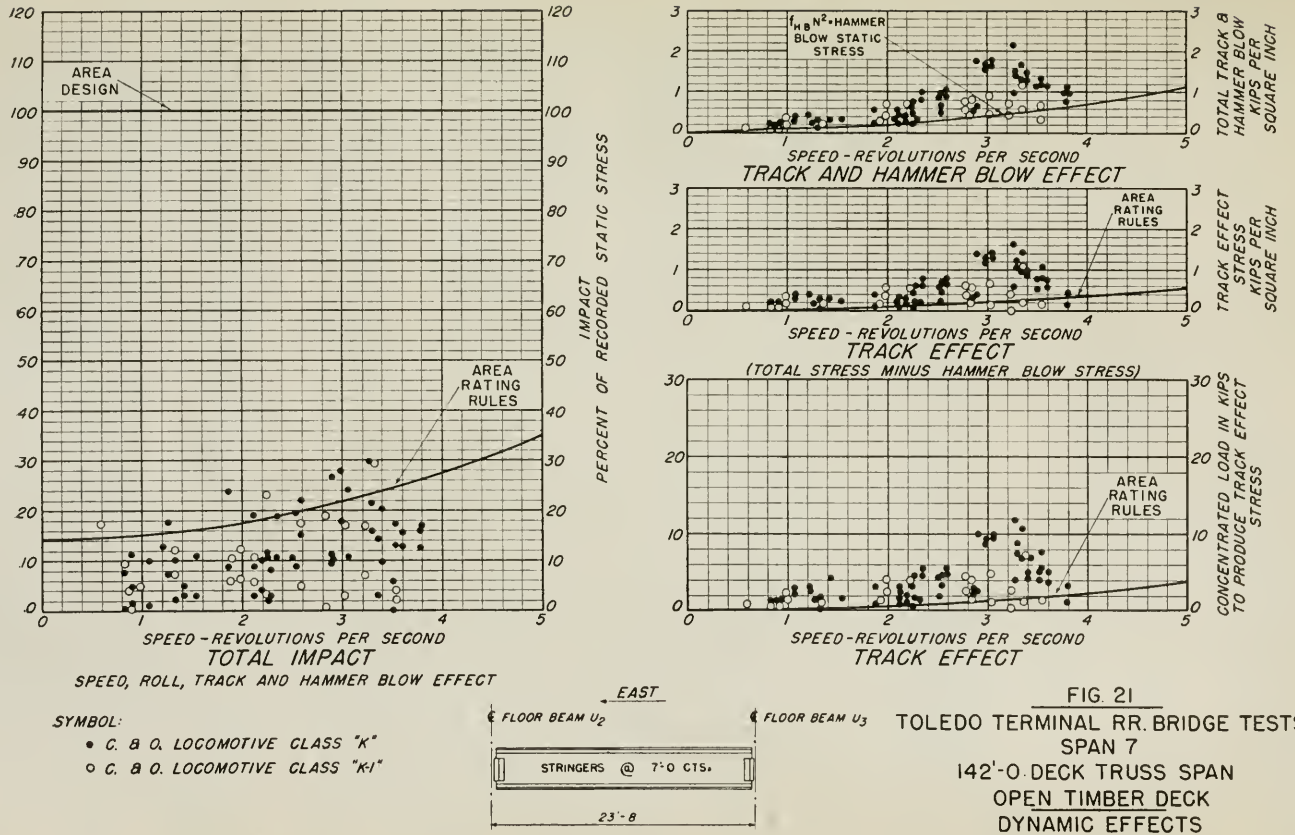

AREA DESIGN
AREA RATING RULES
PERCENT OF RECORDED STATIC STRESS
IMPACT
SPEED - REVOLUTIONS PER SECOND
TOTAL IMPACT
SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT
SYMBOL:
C. & O. LOCOMOTIVE CLASS "K"
C. & O. LOCOMOTIVE CLASS "K-1"
$f_{HB}N^2$ = HAMMER BLOW STATIC STRESS
TOTAL TRACK & HAMMER BLOW KIPS PER SQUARE INCH
SPEED - REVOLUTIONS PER SECOND
TRACK AND HAMMER BLOW EFFECT
AREA RATING RULES
TRACK EFFECT STRESS KIPS PER SQUARE INCH
SPEED - REVOLUTIONS PER SECOND
TRACK EFFECT
(TOTAL STRESS MINUS HAMMER BLOW STRESS)
AREA RATING RULES
CONCENTRATED LOAD IN KIPS TO PRODUCE TRACK EFFECT STRESS
SPEED - REVOLUTIONS PER SECOND
TRACK EFFECT
EAST
℄ FLOOR BEAM U_2
℄ FLOOR BEAM U_3
STRINGERS @ 7'-0 CTS.
23'-8

FIG. 21

TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 7
142'-0 DECK TRUSS SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
STRINGERS U_2 - U_3

(Text continued from page 696)

$$\Delta = \sqrt{\frac{1.0 - k^2\left(1 - \frac{N^2}{n^2}\right)^2}{k^2 \frac{N^2}{n^2}}} \qquad (3)$$

$$k = \frac{1}{\sqrt{\left(1 - \frac{N^2}{n^2}\right)^2 + \left(\Delta \frac{N}{n}\right)^2}} \qquad (4)$$

$$p = \frac{\Delta}{2n} \qquad (5)$$

where:

Δ = damping factor
k = dynamic magnifier
N = speed of locomotive in revolutions per second
n = natural loaded frequency of span in vibrations per second
p = damping constant

In using the above equations in the analysis of these tests, the natural loaded frequency n of the span was determined as previously explained from the average of the plotted values. The value of the damping factor Δ was computed by the use of equation (3), using for k the maximum measured value for a locomotive speed N. Using the computed value of the damping factor Δ, the values of the dynamic magnifier k at all speeds were then calculated from equation (4).

The computed values for the damping factor Δ and the damping constant p are tabulated below the diagrams in Figs. 17 and 18. The value for the damping factor Δ as determined from the 1947 AREA precise rating rules is shown on the diagrams. It can be seen that the damping factor as determined from the tests is considerably lower than that predicated from the 1947 AREA precise rating rules.

142-Ft. Deck Span—Floor Beam Posts, Stringers and Floor Beams

The stress semi-amplitudes as read from the oscillograph film and tabulated in the previously mentioned tables for the floor beam posts, stringers and floor beam of the 142-ft. span are shown in the upper right diagrams of Figs. 19, 20 and 21. The values shown are the average values obtained with two gages on the floor beam post and the maximum values for the floor beam and stringers.

These short spans have natural loaded frequencies of vibration so high that synchronism between the revolving locomotive drivers and the spans cannot occur, and if synchronism should occur it is of such short duration that very little if any magnification of the disturbing force can take place.

Since synchronism did not occur between the revolving locomotive drivers and these members, and it was possible to have only one application of the hammer blow in the center portion of the span, the maximum effect of the centrifugal force of the unbalanced weights in the drivers would be the same as if this force was applied statically on the span.

The semi-amplitudes of stress plotted in the upper diagrams are the combined track and hammer blow effects of the test locomotives. In addition, the unmagnified hammer blow stress curves, $f_{HB}N^2$ are also shown on the upper diagrams by the solid lines for comparative purposes.

The track effect stresses shown in the center diagrams were determined by subtracting the calculated hammer blow stresses from the recorded semi-amplitudes of stress shown in the top diagram. For example, the maximum recorded semi-amplitude of stress

under the class K locomotive on the floor beam posts amounted to 1.89 kips. per sq. in. and occurred at a locomotive speed of 3.29 rps. The calculated hammer blow stress under this locomotive at 3.29 rps. which is subtracted from the recorded semi-amplitude of stress is as follows:

$$f_{HB} N^2 = 0.0273 \times 0.92 \times 3.29^2 = 0.272 \text{ kips. per sq. in.}$$

where

(1) 0.0273 is the calculated hammer blow stress in the member at one revolution per second in kips. per square inch.
(2) 0.092 is the stress factor shown in Table 1.
(3) 3.29 is the locomotive speed in revolutions per second.

The track effect stress is then equal to $1.890 - 0.272 = 1.618$ kips. per sq. in. as shown in the middle diagram of Fig. 19.

The values plotted in the lower diagram of Figs. 19, 20 and 21 are the calculated concentrated loads which would produce the track effect stress shown in the center diagrams. For example, the maximum track effect stress in the floor beam post under the class K locomotive was found to be 1.618 kips per sq. in. The calculated concentrated load to produce a stress of 1.618 kips. per sq. in. is 23.70 kips. as shown in the lower diagram of Fig. 19.

250-Ft. Draw Span—Chord and Web Members

The stress semi-amplitudes as read from the oscillograph film and tabulated in the previously mentioned tables for the test members of the 250-ft. through draw span are shown in the upper right diagrams of Figs. 22 to 31, incl. The values shown are the averages obtained with two gages on each member.

The dynamic magnifiers for the test members of the 250-ft. through draw span are shown in the lower right diagrams of Figs. 22 to 31, incl. The method used in determining the dynamic magnifiers was the same as that used for the 142-ft. deck span. The calculated hammer blow stress at one revolution per second was based on a continuous two-span structure of constant moment of inertia. The crank pins were assumed to be in position for maximum hammer blow and the position of the locomotive and cars on the span at the time of maximum stress was obtained from the oscillograph records.

The dynamic magnifiers as recorded in the end posts and chord members have been plotted in the summary diagram, Fig. 32, while those recorded in the web members are shown in Fig. 33.

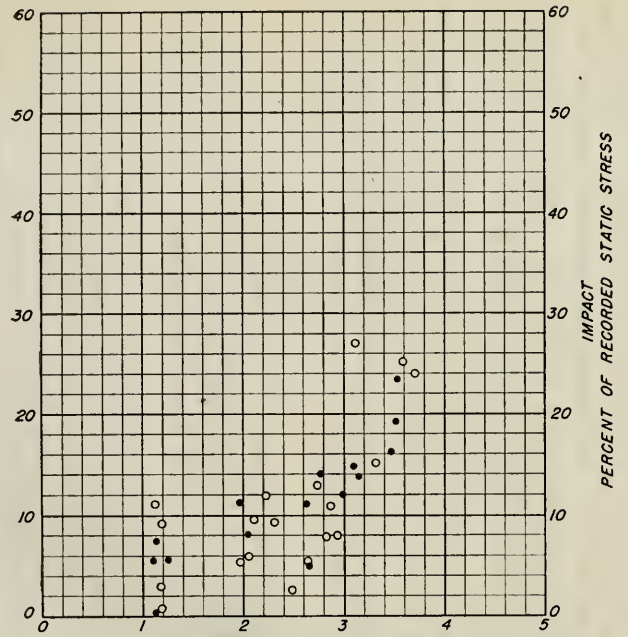
As previously explained, no effort has been made to determine the damping factors for these members as no theoretical analysis has been developed for a continuous span structure such as this.

250-Ft. Through Draw Span—Stringers and Floor Beams

The stress semi-amplitudes, track effect stress and the calculated concentrated loads which would produce the track effect stresses for the stringer and floor beam are shown in the diagrams of Figs. 34 and 35. These values were determined in the same manner as those for the 142-ft. deck span.

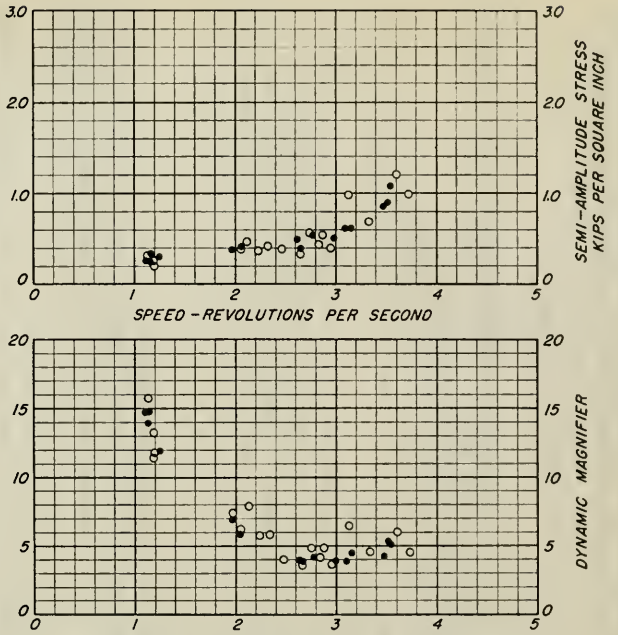
The magnitude of the calculated concentrated loads to produce the track effect stresses on the stringer of the 250-ft. draw span are comparable to those secured on the stringers of the 142-ft. deck span, indicating a similar track condition. The concentrated loads on the floor beam of the 250-ft. draw span are considerably below those secured on the floor beam and floor beam post of the 142-ft. deck span.

(Test continued on page 730)



TOTAL IMPACT

SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT



TRACK AND HAMMER BLOW EFFECT

SYMBOL:

- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K1"

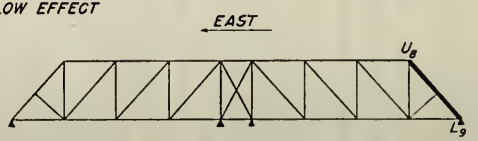
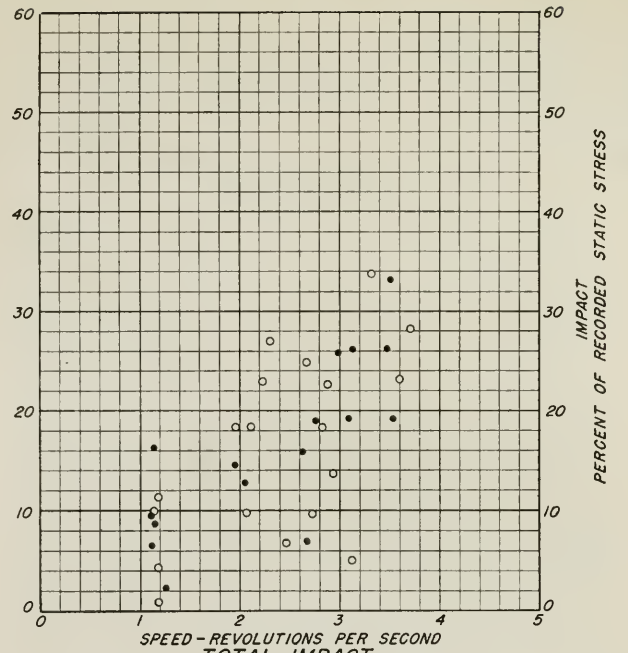


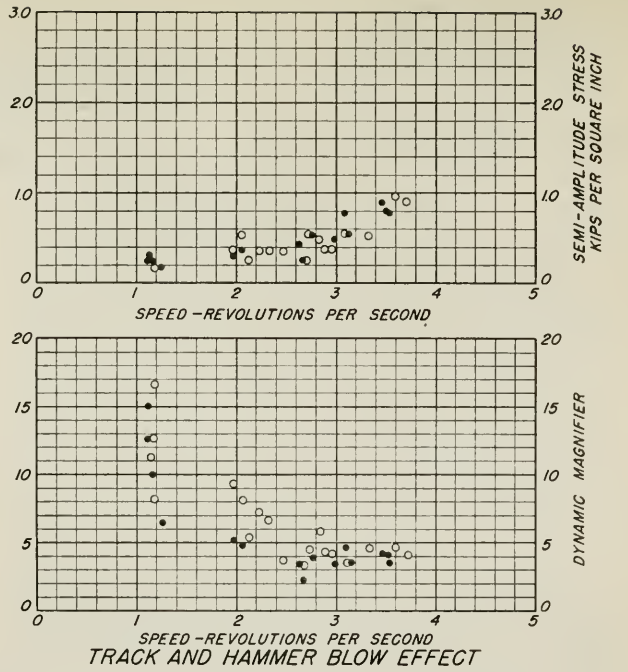
FIG. 22

TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER U_8-L_9



TOTAL IMPACT

SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT



TRACK AND HAMMER BLOW EFFECT

SYMBOL:

- ● C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K-1"

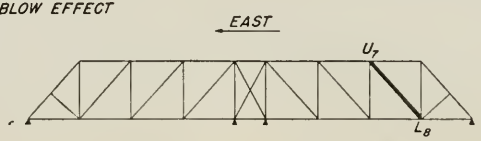
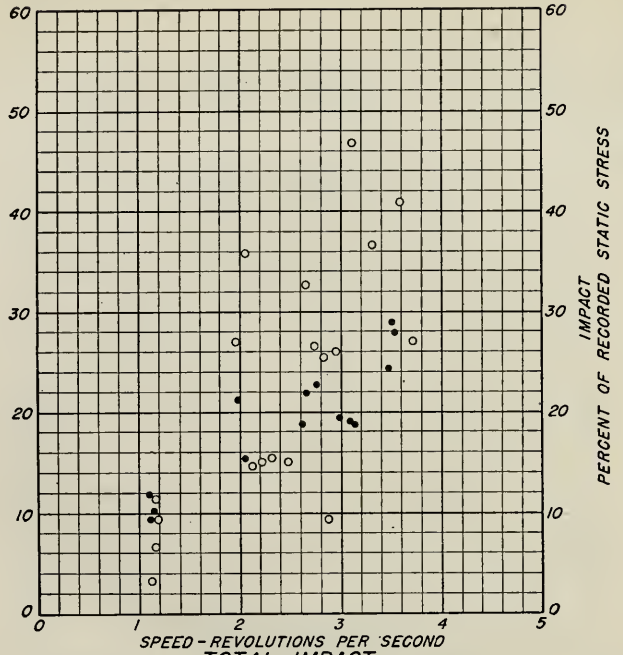


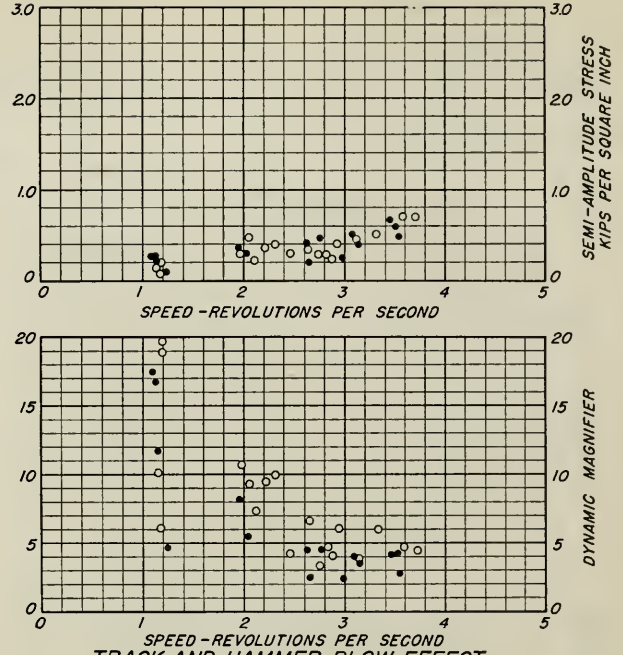
FIG. 23

TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER U_7-L_8



TOTAL IMPACT

SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT



TRACK AND HAMMER BLOW EFFECT

SYMBOL:

- ● C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K1"

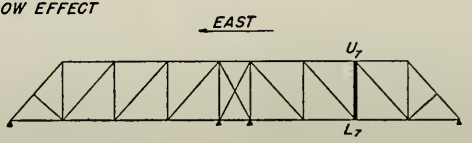
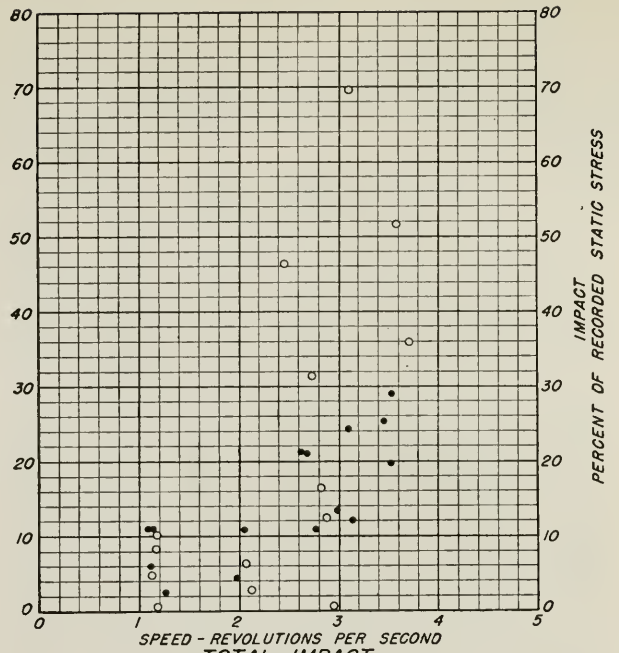


FIG. 24

TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER U_7-L_7

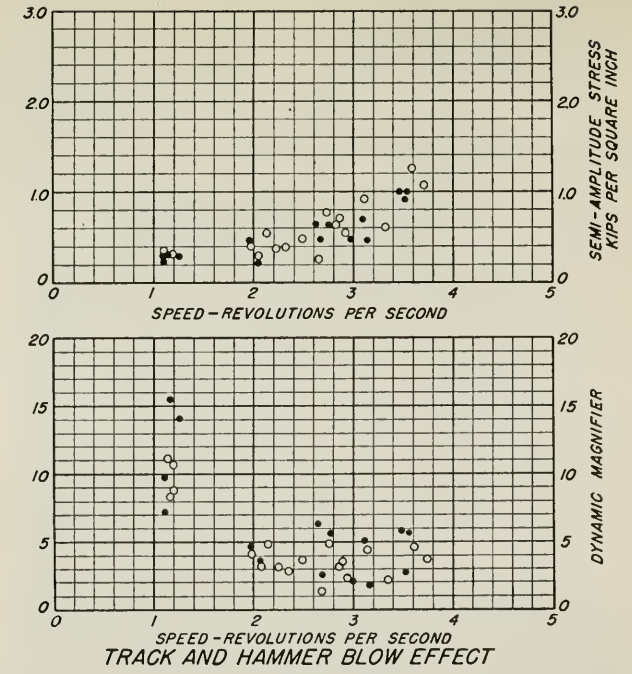


TOTAL IMPACT

SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT

SYMBOL:

- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K-1"



TRACK AND HAMMER BLOW EFFECT

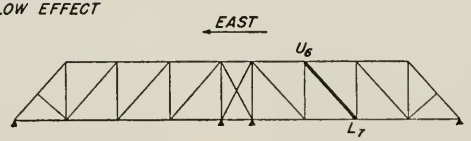
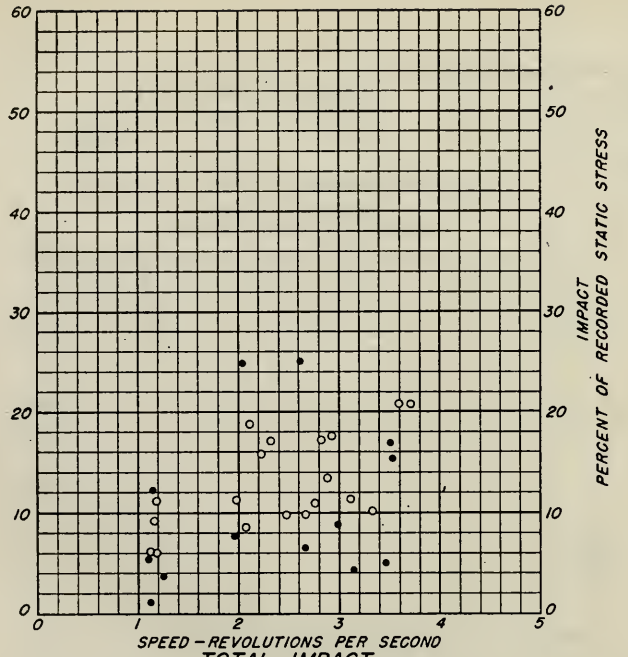


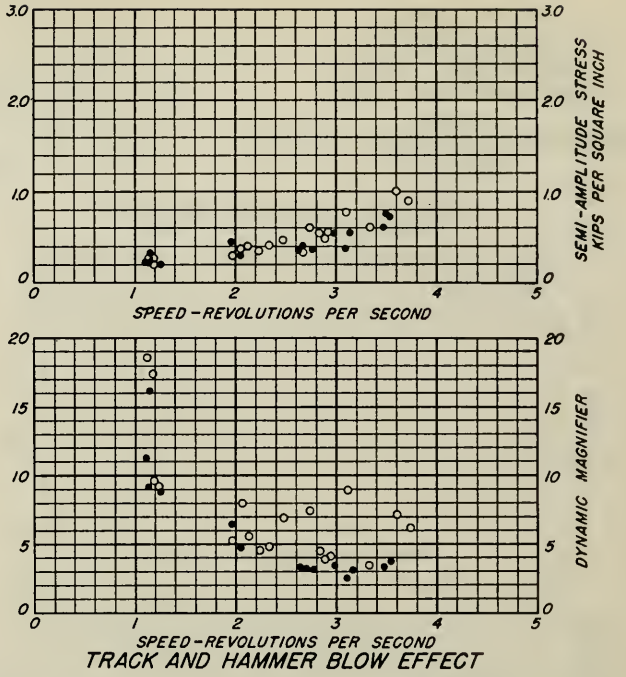
FIG. 25

TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER U_6-L_7



TOTAL IMPACT

SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT



TRACK AND HAMMER BLOW EFFECT

SYMBOL:

- ● C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K1"

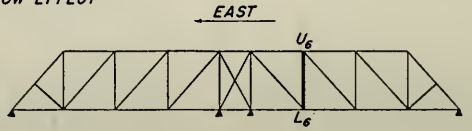
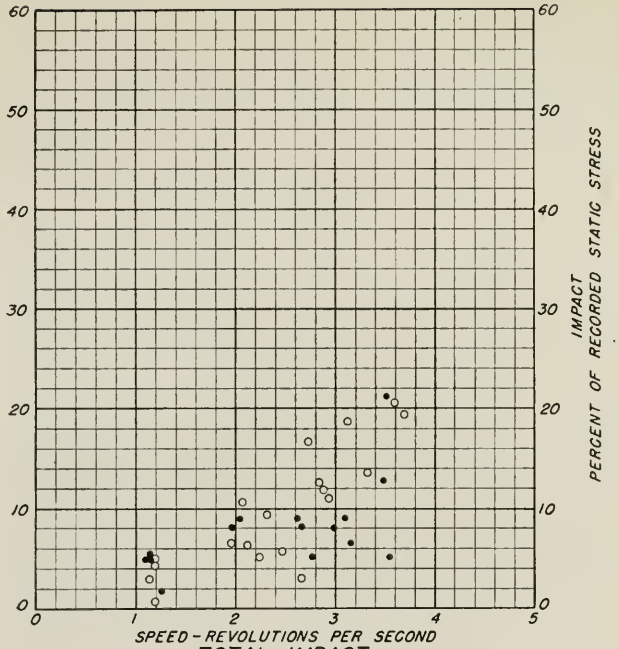


FIG. 26

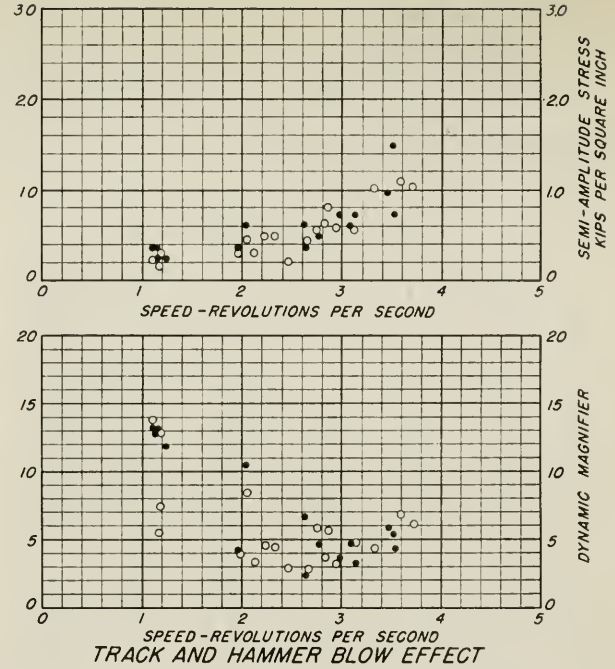
TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER U_6-L_6



TOTAL IMPACT

SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT

SYMBOL:
- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K-1"


SEMI-AMPLITUDE STRESS KIPS PER SQUARE INCH
SPEED - REVOLUTIONS PER SECOND
DYNAMIC MAGNIFIER
SPEED - REVOLUTIONS PER SECOND

TRACK AND HAMMER BLOW EFFECT

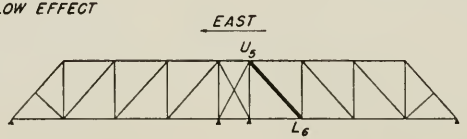
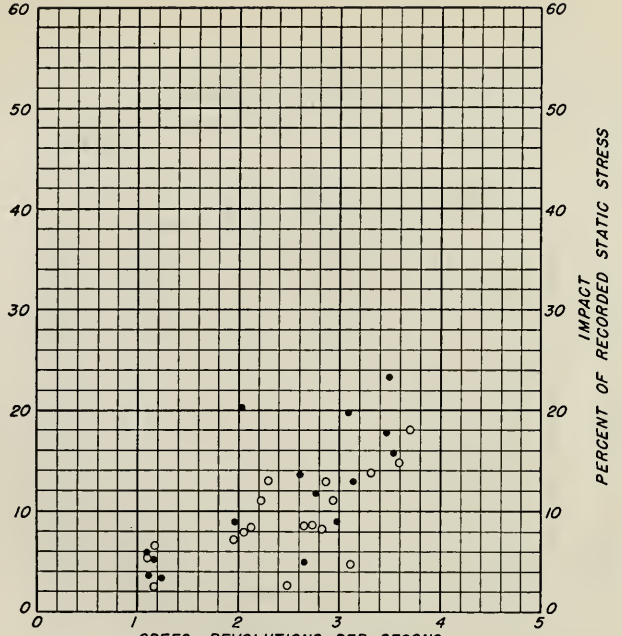


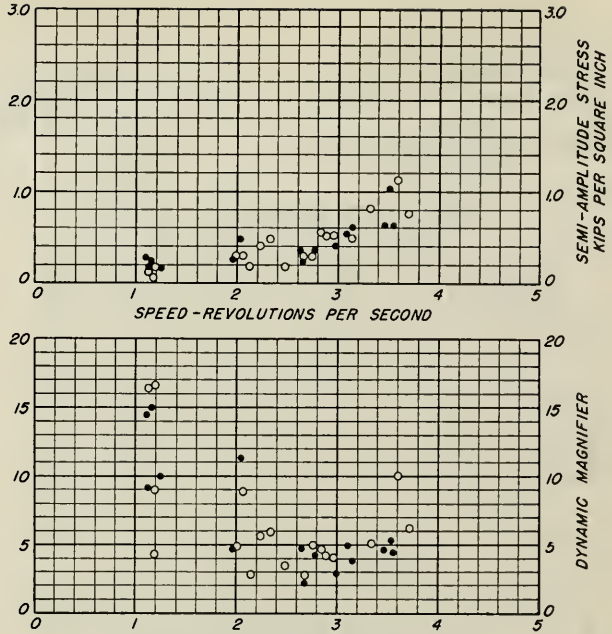
FIG. 27

TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER U_5-L_6



TOTAL IMPACT

SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT


SEMI-AMPLITUDE STRESS KIPS PER SQUARE INCH
SPEED - REVOLUTIONS PER SECOND
DYNAMIC MAGNIFIER
SPEED - REVOLUTIONS PER SECOND

TRACK AND HAMMER BLOW EFFECT

SYMBOL:

- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K-1"

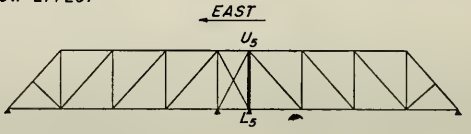
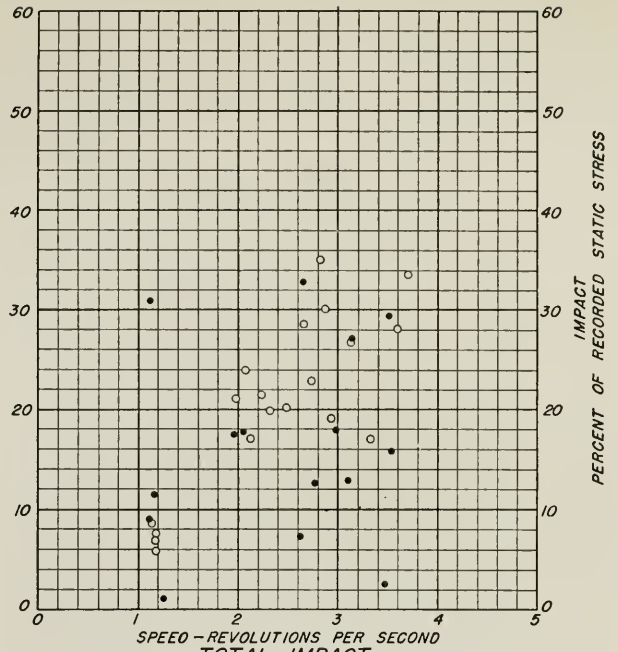


FIG. 28

TOLEDO TERMINAL RR. BRIDGE TESTS.
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER U_5-L_5

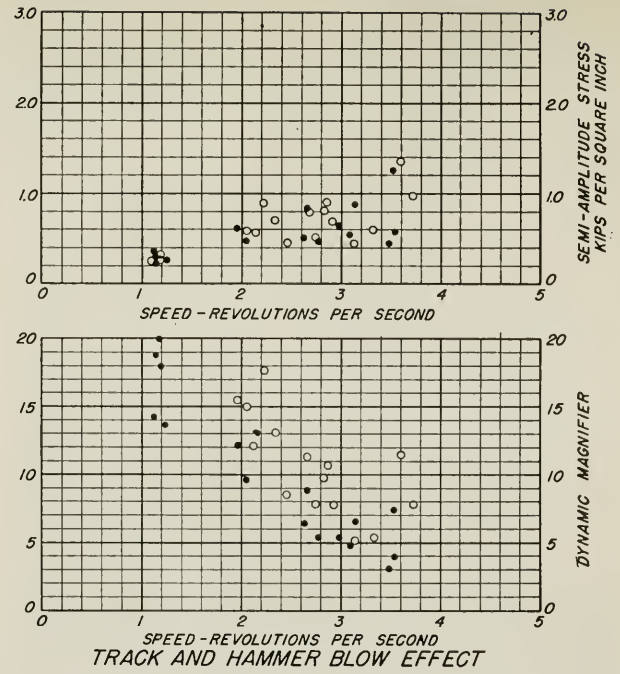


TOTAL IMPACT

SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT

SYMBOL:

- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K-1"



TRACK AND HAMMER BLOW EFFECT

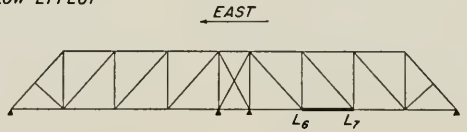
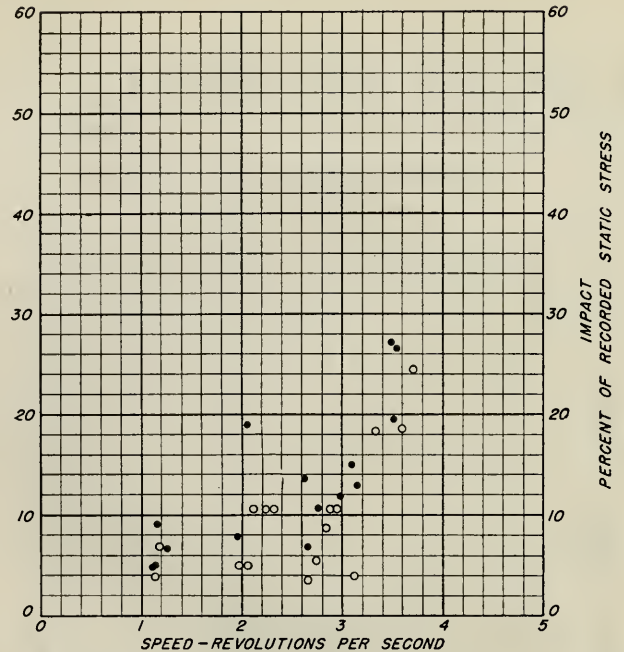
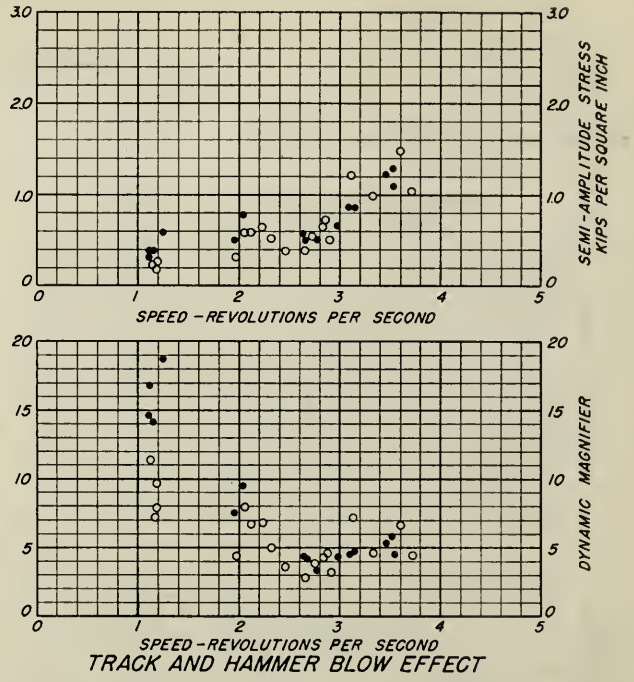


FIG. 29

TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER L_6-L_7


IMPACT
PERCENT OF RECORDED STATIC STRESS
SPEED - REVOLUTIONS PER SECOND
TOTAL IMPACT
SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT



SYMBOL:
- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K-1"

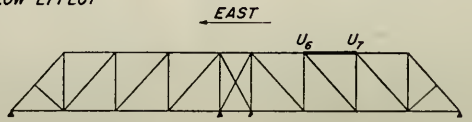
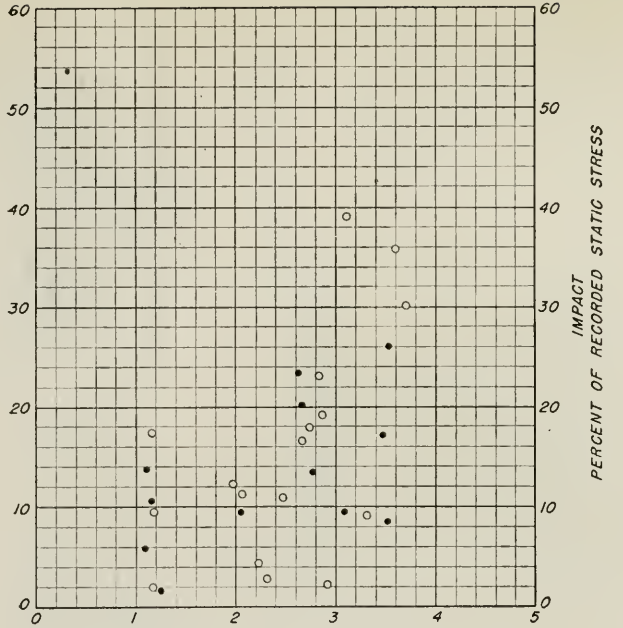


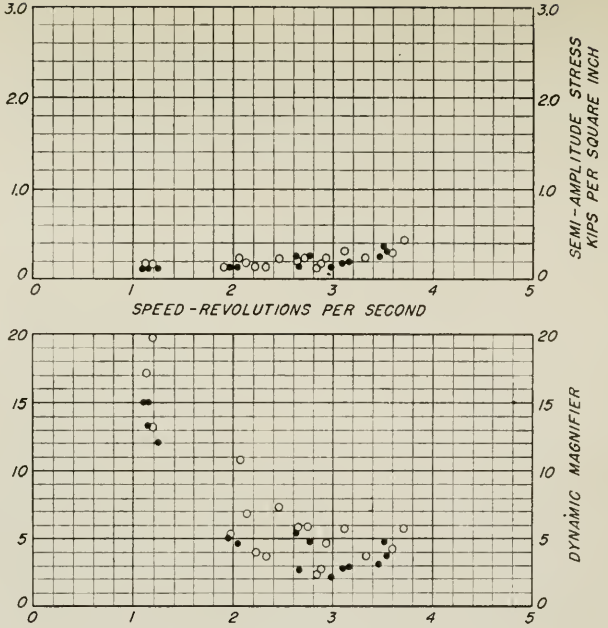
FIG. 30

TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER U_6-U_7



TOTAL IMPACT

SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT



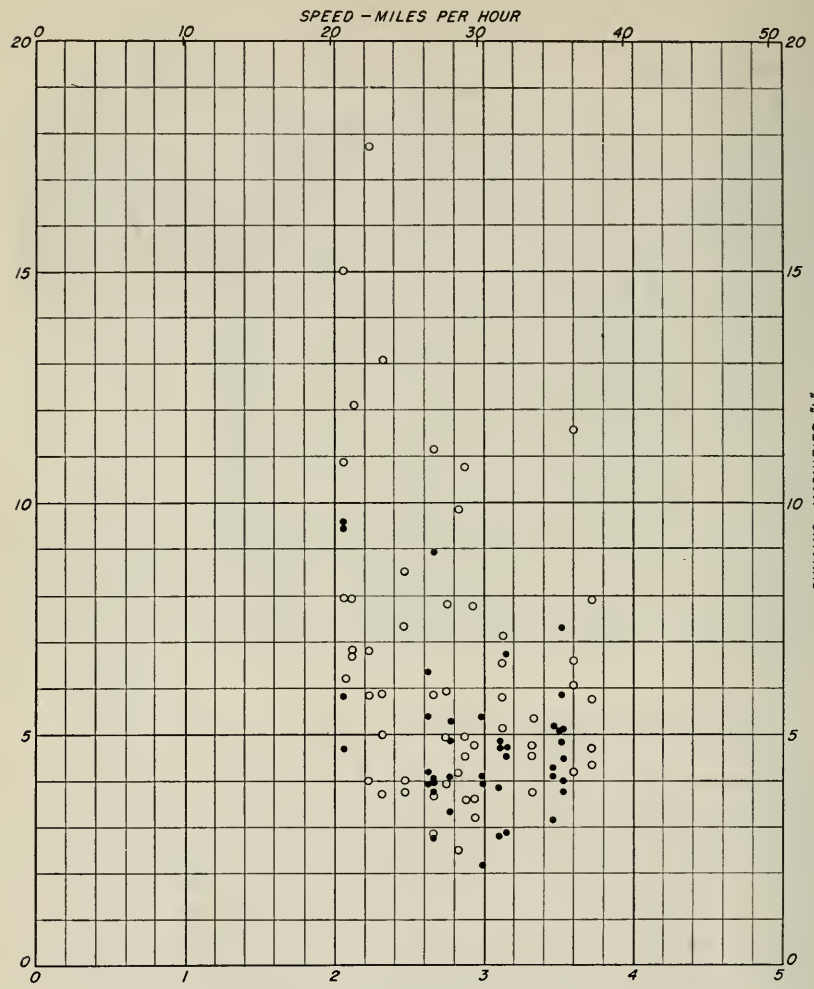
TRACK AND HAMMER BLOW EFFECT

SYMBOL:

- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K-1"

FIG. 31

TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
MEMBER U_4 - U_5



TRACK AND HAMMER BLOW EFFECT

SYMBOL:
- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K-1"

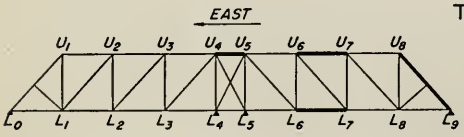
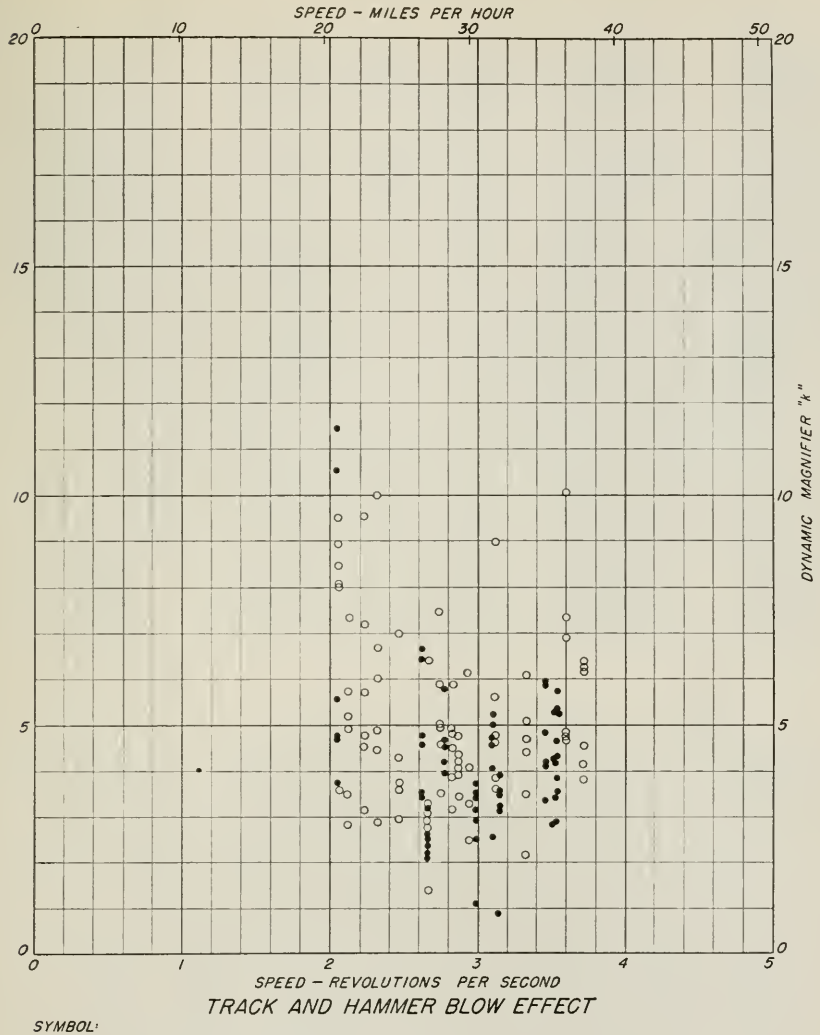


FIG. 32
TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
SUMMARY OF TRACK AND HAMMER BLOW EFFECTS
END POST AND CHORD MEMBERS



TRACK AND HAMMER BLOW EFFECT

SYMBOL:
- ● C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K-1"

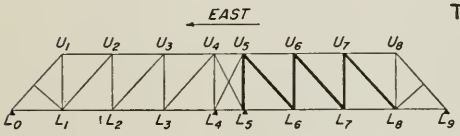
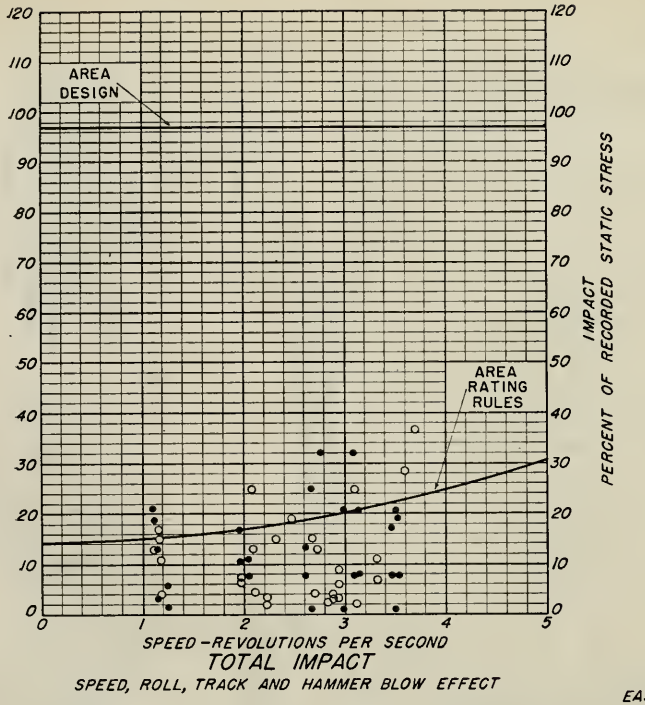
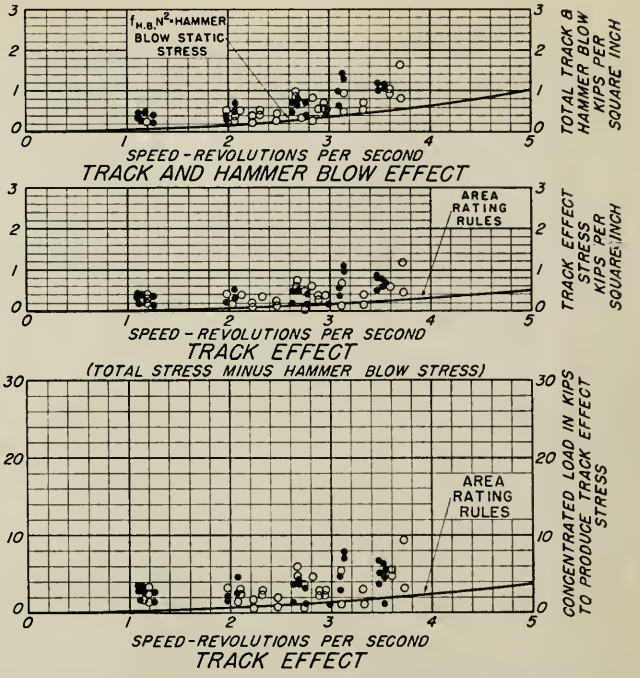


FIG. 33
TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
SUMMARY OF TRACK AND
HAMMER BLOW EFFECTS
WEB MEMBERS




$f_{H.B.}N^2$-HAMMER BLOW STATIC STRESS
TOTAL TRACK & HAMMER BLOW KIPS PER SQUARE INCH
SPEED-REVOLUTIONS PER SECOND
TRACK AND HAMMER BLOW EFFECT
AREA RATING RULES
TRACK EFFECT STRESS KIPS PER SQUARE INCH
SPEED-REVOLUTIONS PER SECOND
TRACK EFFECT
(TOTAL STRESS MINUS HAMMER BLOW STRESS)
AREA RATING RULES
CONCENTRATED LOAD IN KIPS TO PRODUCE TRACK EFFECT STRESS
SPEED-REVOLUTIONS PER SECOND
TRACK EFFECT

SYMBOL:
- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K-1"

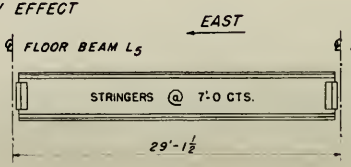
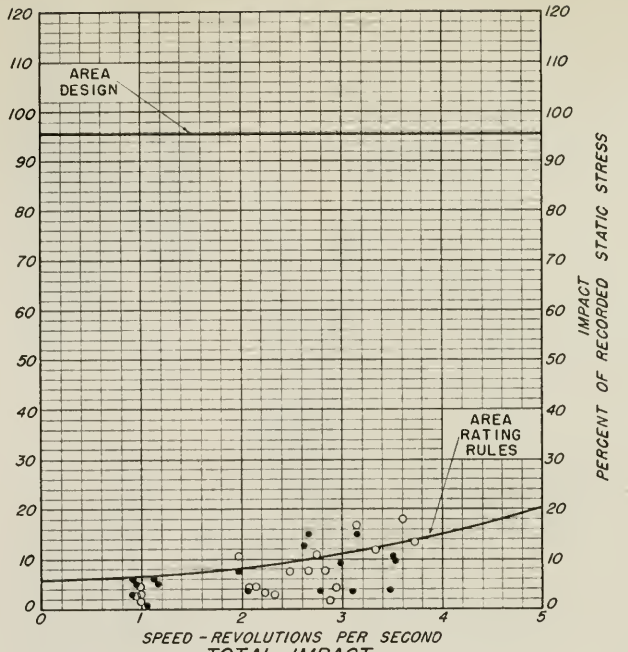
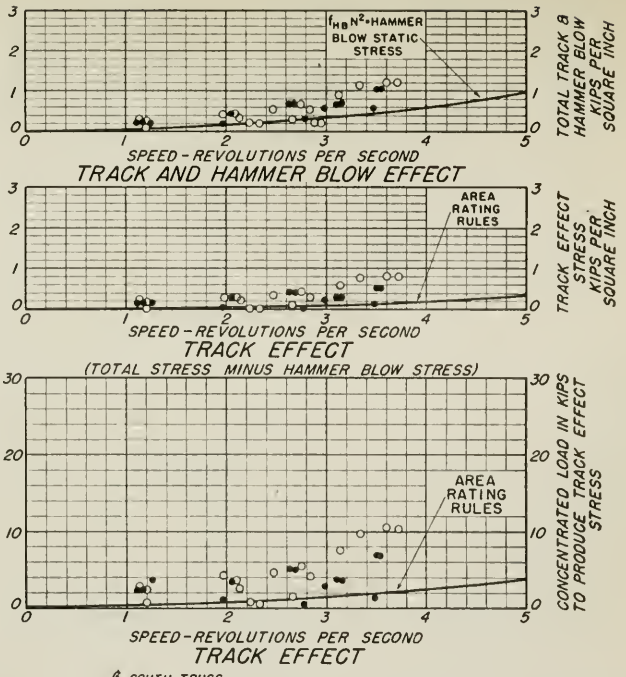


FIG. 34

TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
STRINGERS L_5-L_6




$f_{HB}N^2$ - HAMMER BLOW STATIC STRESS
TOTAL TRACK & HAMMER BLOW KIPS PER SQUARE INCH
SPEED - REVOLUTIONS PER SECOND
TRACK AND HAMMER BLOW EFFECT
AREA RATING RULES
TRACK EFFECT STRESS KIPS PER SQUARE INCH
SPEED - REVOLUTIONS PER SECOND
TRACK EFFECT
(TOTAL STRESS MINUS HAMMER BLOW STRESS)
AREA RATING RULES
CONCENTRATED LOAD IN KIPS TO PRODUCE TRACK EFFECT STRESS
SPEED - REVOLUTIONS PER SECOND
TRACK EFFECT

SYMBOL:

- ● C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K-1"

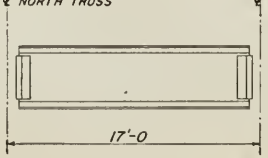
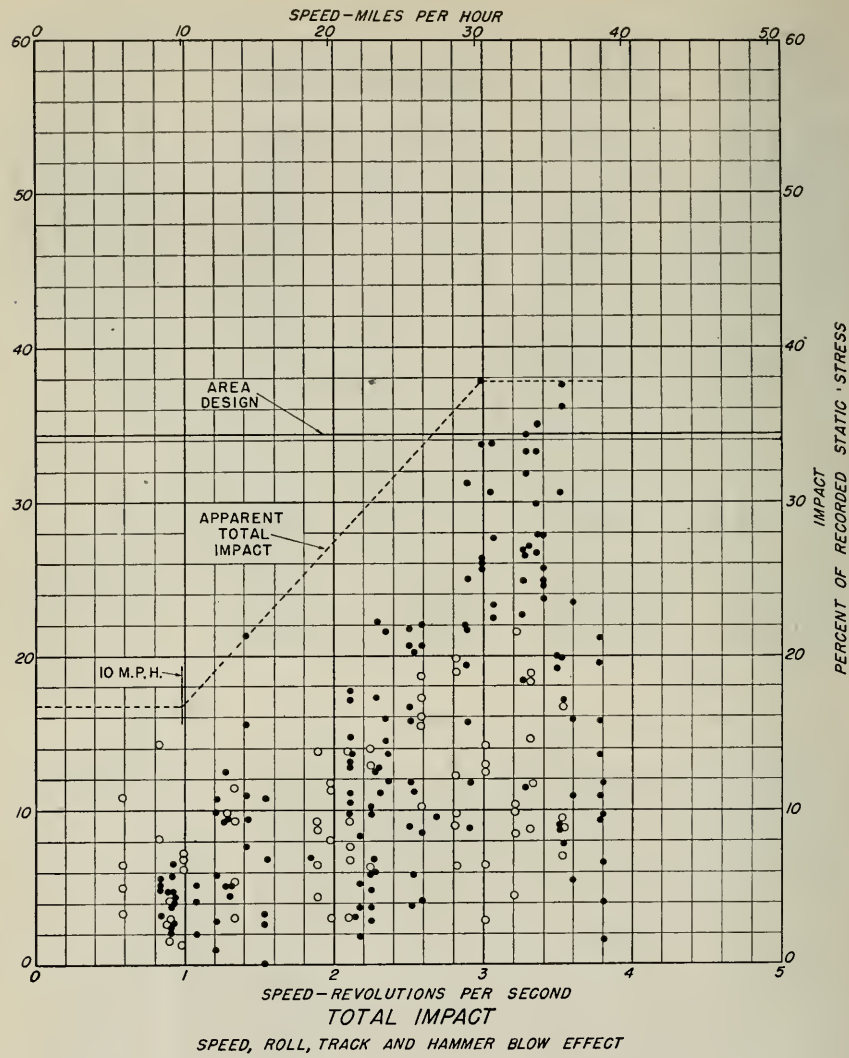


FIG. 35

TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
DYNAMIC EFFECTS
FLOOR BEAM L_6



SYMBOL:
- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K-1"

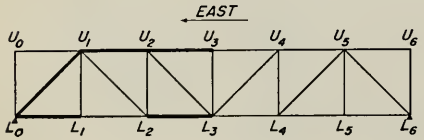
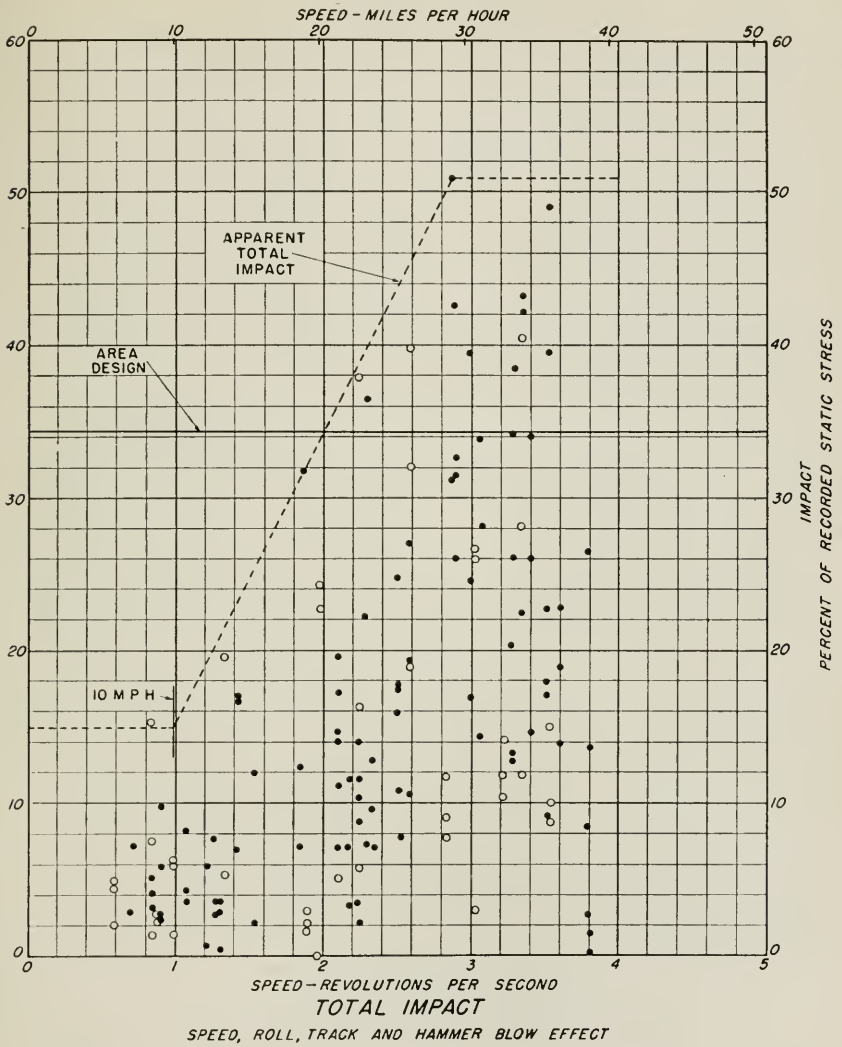


FIG. 36
TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 7
142'-0 DECK TRUSS SPAN
OPEN TIMBER DECK
SUMMARY OF TOTAL IMPACTS
END POST AND CHORD MEMBERS



TOTAL IMPACT

SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT

SYMBOL

● C & O LOCOMOTIVE CLASS "K"

○ C & O LOCOMOTIVE CLASS "K1"

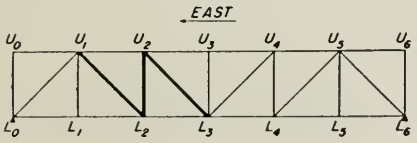
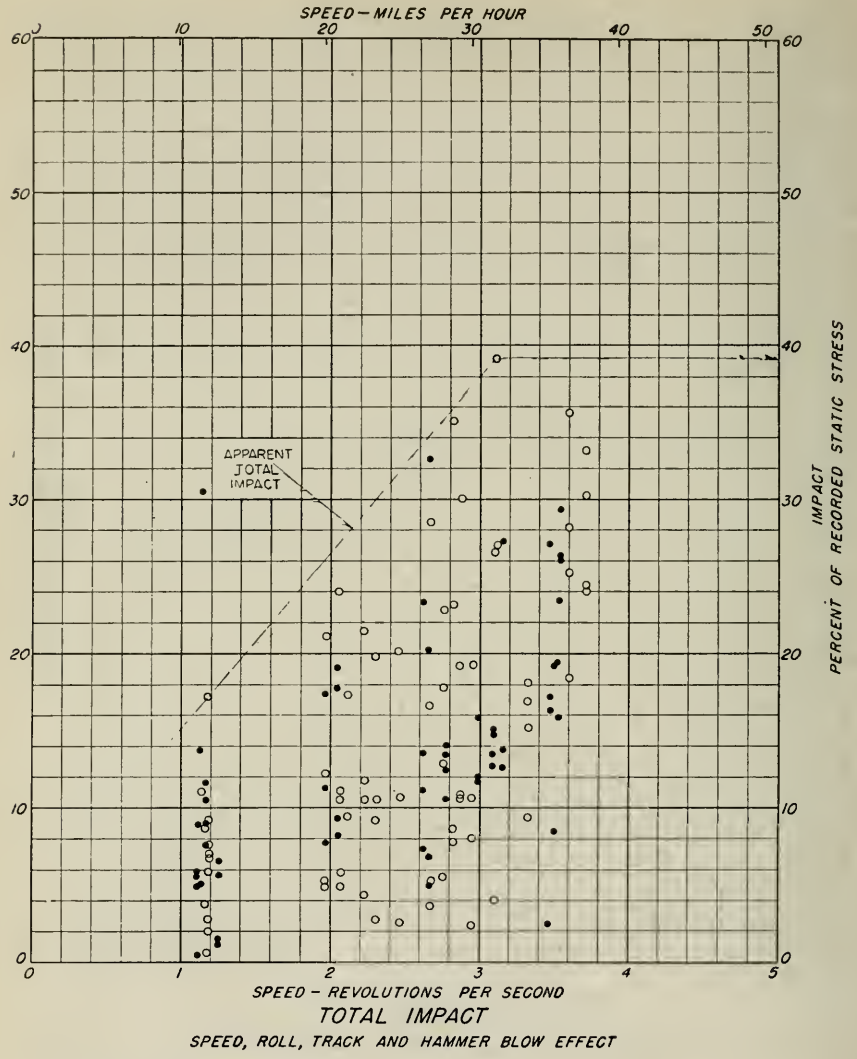


FIG. 37

TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 7
142'-0 DECK TRUSS SPAN
OPEN TIMBER DECK
SUMMARY OF TOTAL IMPACTS
WEB MEMBERS

A


SPEED — MILES PER HOUR
APPARENT TOTAL IMPACT
IMPACT PERCENT OF RECORDED STATIC STRESS
SPEED — REVOLUTIONS PER SECOND
TOTAL IMPACT
SPEED, ROLL, TRACK AND HAMMER BLOW EFFECT

SYMBOL:
- • C. & O. LOCOMOTIVE CLASS "K"
- ○ C. & O. LOCOMOTIVE CLASS "K-1"

← EAST

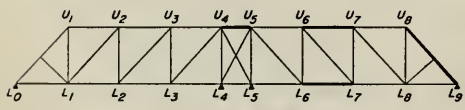


FIG. 38
TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
SUMMARY OF TOTAL IMPACTS
END POST AND CHORD MEMBERS

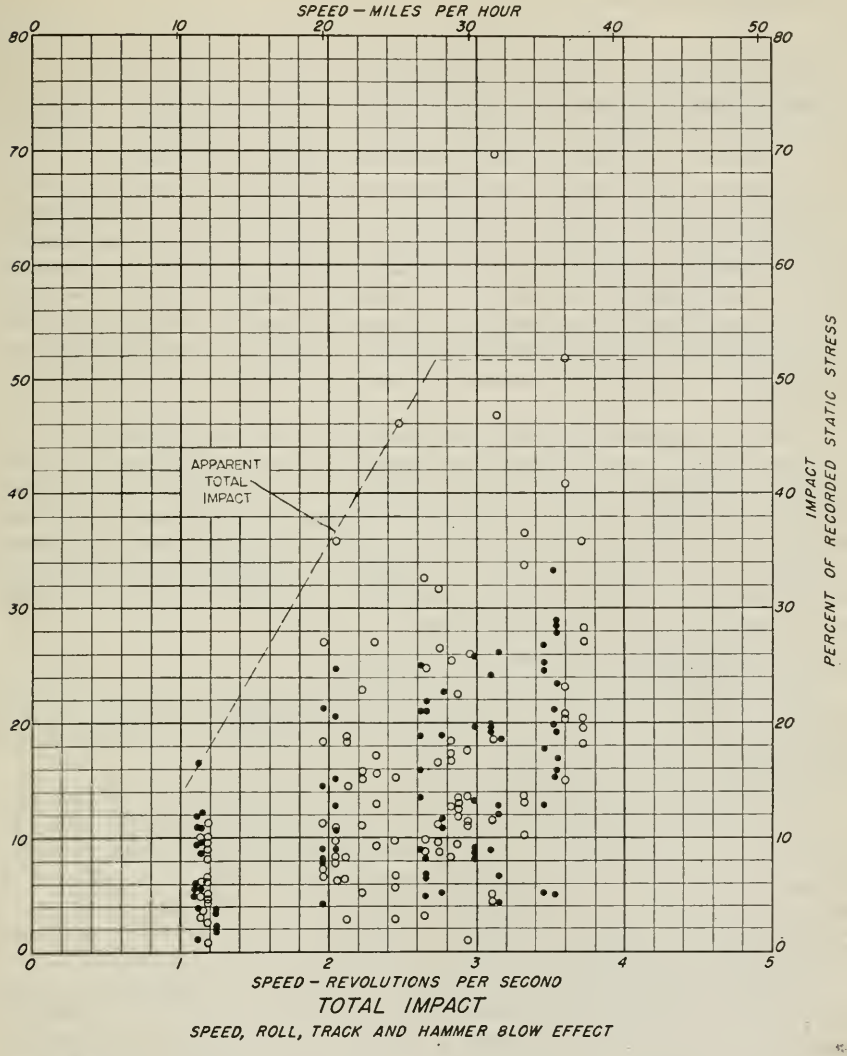


FIG. 39
TOLEDO TERMINAL RR. BRIDGE TESTS
SPAN 6
250'-0 THRU DRAW SPAN
OPEN TIMBER DECK
SUMMARY OF TOTAL IMPACTS
WEB MEMBERS

(Text continued from page 711)

Total Impacts

The total impact percentage is the increase in stress for any particular run over the stress occurring at a slow speed. The total impacts are the combinations of (1) track and hammer blow effects, (2) speed effect and (3) roll effect, although it would be only by chance that the maximum for all effects would occur simultaneously.

The effect of speed, without track and hammer blow effect, is to increase the mean stresses in both trusses over those secured at the low speeds, which has been partly accounted for by the centrifugal force resulting from the load running over the deflected span. Very little is known about the speed effect on the longer spans, but the increase should be quite small. The effect of roll is to increase the mean stresses in one truss with a corresponding decrease in the mean stresses in the other truss. With the gages on the members of one truss only, it is impossible to analyze the separate effects due to speed and roll so only the total impact, which is a combination of the separate effects, is analyzed.

It should be mentioned that the total impacts determined from the results of these tests were obtained under test trains at comparatively low speeds. However, it can be seen from the diagrams of total recorded impacts that the speed of the locomotive drivers in revolutions per second exceeded the natural loaded frequency of vibration of the test spans that the maximum impacts were attained at the synchronous speed, becoming smaller as the locomotive speed exceeded the synchronous speed. It is quite possible that at still higher speeds a second critical speed might have been attained, resulting in possibly still higher total impacts.

142-Ft. Deck Span—Chord and Web Members

The total impact percentages as determined from these tests for the various test members of the 142-ft. deck truss span are shown in the diagrams of Figs. 9 to 16, incl. These diagrams also show the impact percentage as computed by the 1947 AREA design specification and precise rating rules.

It can be noted from these diagrams that in all the members, except the end post L_0 U_1, the recorded total impact is considerably above the value obtained from the precise rating rules and that the impact in several of the members is above the values obtained by the design specification. The variation in total impact in the members of the span is apparently due, as previously explained, to the variable magnification factor of the hammer blow stress for the different members and to the fact that the maximum stress does not occur simultaneously in all the members.

It should be pointed out that two values of total impact in the lower chord L_2 L_3 are above the design specification allowance even though this impact percentage is based upon a recorded static stress which is greater than the calculated static stress.

The total impacts as recorded in the end posts and chord members have been plotted in the summary diagram, Fig. 36, while those recorded in the web members are shown in Fig. 37. Envelope curves have been drawn on both summary diagrams to enclose the values plotted. These envelope curves are called the "apparent total impacts."

It can be seen from these summary diagrams that the apparent total impact for the end posts and chord members is slightly above the AREA design specification, while it is appreciably greater than the AREA design specification for the web members.

142-Ft. Deck Span—Floor Beam Posts, Stringers and Floor Beams

The total impact percentages as determined from these tests for the floor beam posts, stringers and floor beams of the 142-ft. span are shown in the left diagrams of Figs. 19,

20 and 21. The calculated values as recommended in the 1947 AREA design specification and AREA precise rating rules are also shown on these diagrams.

It can be seen that the recorded total impacts are above the values obtained from the rating rules but are considerably below the design specification values. However, it should be kept in mind that the locomotive speeds for these tests were relatively low.

250-Ft. Through Draw Span—Chord and Web Members

The total impact percentages as determined from these tests for the various members of the 250-ft. through draw span are shown in the diagrams of Figs. 22 to 31, incl. Neither the 1947 AREA design specification nor the rating rules specify the impact allowance for a draw or continuous span, so these items could not be shown on these diagrams.

The total impacts as recorded in the end posts and chord members have been plotted in the summary diagram, Fig. 38, while those recorded in the web members are shown in Fig. 39. The "apparent total impacts" have also been drawn on both of these diagrams to enclose the plotted values.

It is interesting to note that the "apparent total impact" in the end posts and chord members of the draw span, which amounted to 39 percent, was quite close to the 38 percent found in the corresponding members of the 142-ft. span. The "apparent total impacts" in the web members of both the 250-ft. draw span and the 142-ft. deck span were appreciably higher than those found in the end posts and chord members, amounting to 52 percent in the draw span and 51 percent in the deck span.

250-Ft. Draw Span—Stringers and Floor Beams

The total impact percentages as determined from these tests for the stringers and floor beams of the 250-ft. draw span are shown in the left diagrams of Figs. 34 and 35. The calculated values as recommended in the 1947 AREA design specification and precise rating rules are also shown on these diagrams.

The recorded total impacts in these members are above the values obtained from the 1947 precise rating rules but are considerably below the design specification which agreed with the results found in the comparable members of the 142-ft. deck span. However, the locomotive speeds for these tests were also relatively low.

8. Rating of the Spans

The primary purpose of conducting these tests, as previously explained, was to determine the stresses in typical main members of the trusses and then base the carrying capacity upon these stresses. It should be understood that the rating of these spans is based upon test results only, and does not include the calculated stresses due to wind pressure.

The rating of all the members of these spans is of no general interest so only the determination of the rating of a typical tension and compression member will be shown.

Rating of Tension Member L_2 L_3 (Span 6)

The 1947 AREA rules for rating existing bridges specify that the maximum stress, based on the net section of the member, shall not exceed 0.8 of the yield point of the steel for tension members. It was assumed that the medium carbon steel in this bridge had a yield point of 30,000 psi., so an allowed stress of 24,000 psi. was used in determining the rating of the tension members of the bridge.

The electromagnetic gages were so located on the members that the stresses were recorded on the gross section. Since the allowed stress is based upon the net section,

it is necessary to consider the ratio of the net section to the gross section in rating the member.

The rating of member L_2 L_3, in terms of Cooper loading, was determined in the following manner:

A_N = net area of member = 29.69 sq. in.
A_G = gross area of member = 36.30 sq. in.
Ratio $\frac{A_N}{A_G} = \frac{29.69}{36.30} = 0.819$

f_G = allowable unit stress on gross section = $24.00 \times 0.819 = 19.65$ kips. per sq. in.
B = average bending (see Table 3) = 13.2 percent.
F = average stress factor (see Table 1) = 1.31.
I = impact in end posts and chord members (see Fig. 36) = 38 percent.
f_G^{DL} = calculated dead load gross unit stress = 3.05 kips. per sq. in.
f_G^{E-10} = calculated static unit stress on gross section under Cooper E–10 loading = 1.66 kips. per sq. in.

$$\text{RATING} = \frac{\left(f_G - f_G^{D.L.}\right) 10}{f_G^{E\text{-}10} \times F \times (1+B) \times (1+I)} = \frac{(19.65 - 3.05)\ 10}{1.66 \times 1.31 \times 1.132 \times 1.38} = \text{E-48.8}$$

Rating of Compression Member L_0 U_1 (Span 6)

In determining the rating of compression members with known eccentricity of load, the 1947 AREA rules for rating existing bridges specify that the maximum direct stress, based on the gross section of the member, shall not exceed the stresses as found by the secant formula in Appendix A of the 1947 AREA design specification. The values for the yield point, factor of safety and modulus of elasticity were assumed to be:

y = yield point = 30,000 psi.
f = factor of safety = 1.20
E = modulus of elasticity = 30,000,000 psi.

The allowable average compressive unit stress in member L_0 U_1, as determined from the secant formula, is as follows:

$$p = \frac{\frac{y}{f}}{1 + \left[\left(\frac{e_1 c_1}{r_1^2}\right) \times \sec \frac{0.75 l}{2 r_1} \sqrt{\frac{f \cdot p}{E}}\right] + \left[\left(\frac{e_2 c_2}{r_2^2}\right) \times \sec \frac{0.75 l}{2 r_2} \sqrt{\frac{f \cdot p}{E}}\right]}$$

where,

l = length of member = 402 in.
r_1 = radius or gyration about horizontal axis = 5.59 in.
c_1 = distance from horizontal neutral axis to extreme fiber = 8.84 in.
r_2 = radius of gyration about vertical axis = 5.23 in.
c_2 = distance from vertical neutral axis to extreme fibre = 6.25 in.
e_1 = average eccentricity about horizontal neutral axis (see Table 3) = 0.41 in.
e_2 = average eccentricity about vertical neutral axis (see Table 3) = 0.89 in.
p = allowable average compressive unit stress

Then

$$p = \frac{\frac{30,000}{1.20}}{1+\left[\left(\frac{0.41\times 8.84}{5.59^2}\right)\sec\frac{0.75\times 402}{2\times 5.59}\sqrt{\frac{1.20p}{30,000,000}}\right]+\left[\left(\frac{0.89\times 6.25}{5.23^2}\right)\sec\frac{0.75\times 402}{2\times 5.23}\sqrt{\frac{1.20p}{30,000,000}}\right]}$$

$$p = \frac{25,000}{1+0.154+0.282} = \frac{25,000}{1.436} = 17,400 \text{ lb. per sq. in.}$$

It should be pointed out that the coefficient 0.25 in the denominator of the formula to provide for the inherent crookedness and unknown eccentricity has been omitted, as the exact eccentricity at the center of the member resulting from all factors has been determined from the strain gage readings.

The rating of member $L_0\ U_1$, in terms of Cooper loading, was then determined in the following manner:

F = average stress factor = 1.22
f_G^{DL} = calculated dead load unit gross stress = 2.76 kips. per sq. in.
f_G^{E-10} = calculated static unit stress on gross section under Cooper E-10 loading = 1.54 kips. per sq. in.
I = impact in end post and chord members (see Fig. 36) = 38 percent.

$$\text{RATING} = \frac{(p - f_G^{D.L.})10}{f_G^{E-10}\times F\times(1+I)} = \frac{(17.40-2.76)10}{1.54\times 1.22\times 1.38} = E\text{-}56.4$$

9. Conclusions

These tests afforded an opportunity to measure and compare the simultaneous stresses on the four corners of any member as well as the simultaneous stresses in several members, providing certain information not heretofore available.

Many interesting and valuable data were obtained but it must be remembered that these tests represent but one span of each type and while there is evidence that certain factors are more important than had been generally realized, it is recommended that these factors be verified by further tests.

From the data, as found from these tests, it seems logical to conclude that:

1. Static Stresses

The actual static stresses in the top chord of the 142-ft. deck truss span are appreciably lower than the calculated stresses, while the stresses in the bottom chord are greater. The variation between the actual and calculated stresses is believed to be due to the action of the stringers in taking direct stress. There is fair agreement between the actual and calculated static stresses in the web members.

The actual static stresses in the chord and web members of the 250-ft. through truss draw span agree well with the calculated stresses in these members. The agreement between the actual and calculated stress indicates that the method of calculating the stresses based on the continuous action of a two-span structure of constant moment of inertia and assuming that the center panel over the rim-bearing support could transmit moment but no shear, is fairly accurate when the wedges are properly adjusted.

2. Secondary Stresses

The secondary stresses or the bending stresses resulting from the rotation of the joints were greater than would normally be expected in structures of this type. It

appears that the deflection of the stringers and floor beams have a marked influence on the bending stresses in the members.

3. Distribution of Stress over Section

There is evidence that the stress does not vary uniformly over the section of the members.

4. Track Effect Stresses in Stringers and Floor Beams

The track effect stresses in the stringers and floor beams were considerably greater than those specified in the 1947 AREA rules. These stresses were about the same as those found in other tests on short spans.

5. Track and Hammer Blow Effects

The track and hammer blow effects in the 142-ft. deck span were considerably greater in the individual members of the trusses than those predicated by the 1947 AREA precise rating rules. It is evident that either the amount of damping in this span was not as great as that specified in the rating rules or else the magnification of the hammer blow is not the same for all members of the span.

6. Total Impacts

The total impacts in the 142-ft. deck truss span are greater than those specified by both the 1947 AREA design specifications and the precise rating rules. The impacts in the web members were appreciably greater than those in the end posts and chord members.

The total impacts in the 250-ft. through truss draw span cannot be compared with the 1947 AREA design specifications or rating rules as they make no provision for the calculation of impact in such a structure. However, there was good agreement between the impacts in the members of the two spans, indicating that the impact in a two-span continuous structure is about the same as that in a simple span.

The total impact in the individual members of a truss under dynamic loading cannot be predicated by the action of the structure as a whole. For this reason, total impacts in truss members should be determined by strain gage reading. It would appear desirable in future tests to secure both strain gage readings and center deflection readings.

7. Rating of the Span

The carrying capacity or rating of old spans can be accurately determined by strain gage measurements.

10. Acknowledgment

The Committee on Impact and Bridge Stresses and the American Railway Engineering Association are deeply indebted to the Toledo Terminal Railroad for the use of the data covering these tests.

Effect of Weight Redistribution on the Magnitude of Lateral Forces Exerted by a Locomotive

Report on Measurements Made on the Rails of a 4-Deg. Curve in the Southbound Main Track of the Illinois Central Railroad near Curve, Tenn.

Digest of Report

This report describes an investigation conducted by the Engineering Division research staff of the Association of American Railroads for the Joint Committee on Relation Between Track and Equipment* in cooperation with the Illinois Central Railroad, to determine the extent to which the lateral forces exerted by a moving locomotive on the rails of curved track are modified by the transfer of weight from the driving wheels to the leading and trailing wheels of a Mikado locomotive. The redistribution of weight had been made in order to lower bridge stresses, and it was thought that the addition of weight to the engine and trailer trucks might increase the lateral forces exerted on the rails of curves. Some difficulty had been experienced with spread gage following the redistribution of the weight of locomotives in this manner. The test data, however, indicate that no substantial change in the magnitude of the lateral forces was effected by the weight redistribution.

The data obtained on the lateral forces produced on each rail by each wheel are of general interest in showing the guiding forces which act upon a locomotive of this type when operated on curved track at various speeds.

Foreword

In the operation of Mikado locomotives, Class 1200–1499 (2–8–2), the Illinois Central Railroad experienced some difficulty on its Gulf & Ship Island branch line because of gage spread on a 4-deg. curve laid with 90-lb. rail. As a part of an investigation made to determine the cause of the trouble, it was decided to measure the lateral forces exerted on the rails of a 4-deg. curve in the southbound main track near Curve, Tenn., where a test was scheduled for the measurement of stresses in tie plates.

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* The Joint Committee on Relation Between Track and Equipment was appointed by the vice-president of the Operations and Maintenance Department, AAR, to study and report on problems of interest to both the Engineering and Mechanical Divisions. Its membership is as follows:

K. Cartwright (chairman), chief mechanical engineer, New York, New Haven & Hartford Railroad, New Haven, Conn.
E. M. Hastings, chief engineer, Richmond, Fredericksburg & Potomac Railroad, Richmond, Va.
W. J. Burton, assistant to chief engineer, Missouri Pacific Railroad, St. Louis, Mo.
A. G. Hoppe, general superintendent, locomotive and car department, Chicago, Milwaukee, St. Paul & Pacific Railroad, Milwaukee, Wis.
V. R. Hawthorne, executive vice-chairman, Mechanical Division, AAR, Chicago.
J. R. Jackson, mechanical engineer, AAR, Chicago.
W. S. Lacher, secretary, Engineering Division, AAR, Chicago.
G. M. Magee, research engineer, Engineering Division, AAR, Chicago.

Object of Tests

The purpose of this investigation was to determine the lateral forces exerted on the rails of a 4-deg. curve by Mikado-type locomotives and to compare these forces for a typical improved Mikado locomotive having original distribution of weight with a locomotive that had its weight redistributed by transferring some of the weight on the drivers to the engine and trailing trucks.

Test Locomotives

Engines 1347 and 1357 (2–8–2) were selected for the tests. Engine 1347 was one of the locomotives which had its weight redistributed for operation over the wood stringer bridges of the G. & S. I., while Engine 1357 had the same arrangement of equalization as originally built. The weights in working order of these locomotives are shown in Table 1. Line (3) shows principally the change in weights of Engine 1347 when the equalization system was modified and line (5) gives the differences in weights of the two locomotives when tested. The engine and trailer trucks of Engine 1347 were 6560 and 11,760 lb. heavier, respectively, than the corresponding trucks of Engine 1357. It was thought that Engine 1347 with the heavier loads on its trucks might be causing most of the trouble on the 4-deg. curves of the G. & S. I.

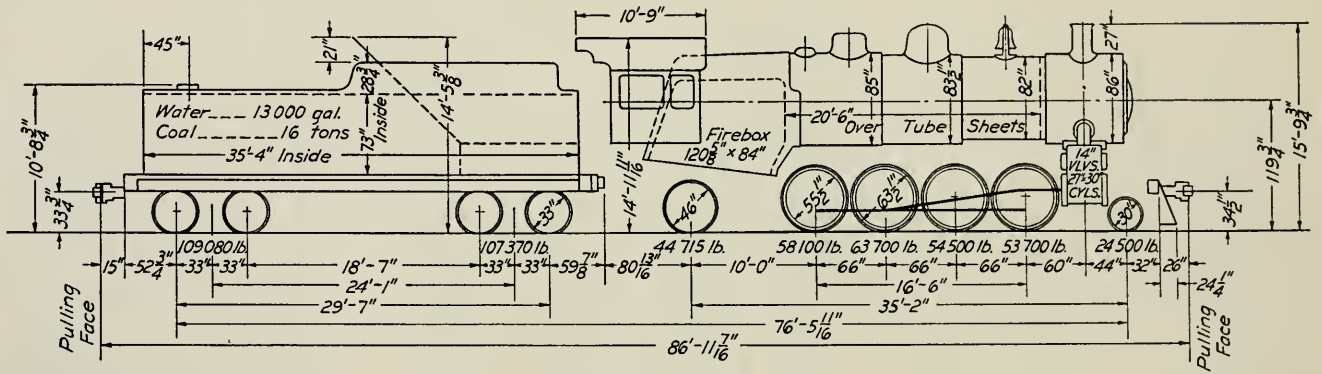
A locomotive diagram of Engines 1347 and 1357 is presented in Fig. 1. The two test locomotives were not equipped with lateral motion devices. Each had the same drawbar arrangement which consisted of a main drawbar of 3 in. by 6 in. cross section and double safety bars, one on each side of the main drawbar. The buffer on Engine 1347 was of an old design with two coil springs while the one on Engine 1357 was of the slack wedge type. The engine truck on the two test locomotives was of the swing hanger type with coil springs and inside bearings, and had a constant resistance of 16⅔ percent. The trailer trucks were of the built-up type with outside bearings and spring centering. Engine 1347 had the centering spring in place which provided an initial resistance of zero and a maximum resistance of 22.4 percent with the springs solid.. The centering spring of the trailer of Engine 1357 had been removed. Engine 1347 had tires 3¾ in. thick while for Engine 1357 they were 2⅞ in. thick. The tires on both engines were in good condition and had only a moderate amount of flange wear. The mileage of Engines 1347 and 1357 since the last general shopping was 35,000 and 20,000 miles, respectively. The hub lateral in the driving wheels of each of the two Mikado locomotives varied from 3/16 to 5/16 in. Each locomotive was in good mechanical condition and well broken in.

Test Track

The tests were made on the 4-deg. curve to the right in the southbound track on Mile L–333. The curve was approximately 1600 ft. long and located near the end of a 5-mile ascending grade. The curve had a 4⅛-in. superelevation with a balanced speed of 40 mph. The track was laid with 112-lb. RE rail, double shoulder tie plates and creosoted oak ties which were applied new in 1944. It was surfaced with fine slag ballast and was in good condition. The gage was ¼ in. wide. The eight special roller bearing tie plates which were used to measure the outward and inward lateral forces on each rail separately, were located on four consecutive ties near the middle of the curve. The roller bearing tie plate consists, principally, of a base plate with an upturned leg outside of the rail and a nest of roller bearings resting on the base plate, supporting another plate on which the rail rests. The assembly is attached to the tie with four through bolts. The lateral thrust on the rail is transmitted from the rail web to the

TABLE 1.—WEIGHTS OF MIKADO TYPE LOCOMOTIVES IN 1000 LB.

Locomotive	*Line*	*Trailers*	*Rear Drivers*	*Main Drivers*	*Inter. Drivers*	*Front Drivers*	*Eng. Truck*	*Total Drivers*	*Total Eng.*
Eng. 1347, Weights as of Aug. 7, 1940	(1)	51.68	55.98	57.02	57.12	55.54	29.82	225.66	307.16
Eng. 1347, Modified weights (As tested)	(2)	54.84	53.48	53.68	57.98	56.62	31.54	221.76	308.14
Differences: (2)—(1)	(3)	+ 3.16	— 2.50	— 3.34	+ 0.86	+ 1.08	+ 1.72	— 3.90	+ 0.98
Eng. 1357, As tested	(4)	43.08	62.90	70.20	53.86	53.84	24.98	240.80	308.86
Differences: (2)—(4)	(5)	+ 11.76	— 9.42	— 16.52	+ 4.12	+ 2.78	+ 6.56	— 19.04	— 0.72
Class 1200–1499, Mfr's estimated weights	(6)	44.715	58.10	63.70	54.50	53.70	24.50	230.00	299.215



Designed for a 16° Curve

Cylinders	27" × 30"
Valves	14"
Driving Wheels	63 1/2"
Weight on Drivers, Working Order	230 000 lb.
Weight Total Engine, Working Order	299 215 lb.
Weight Tender, Working Order	216 450 lb.
Weight Engine and Tender, Working Order	515 665 lb.
Tubes, Number and Diameter	262 — 2" dia.
Flues, Number and Diameter	36 — 5 3/8" dia.
Grate Area	70.4 sq. ft.

	Eng. 1347	Eng. 1357
Heating Surface, Arch Tubes	316 sq. ft.	—
Heating Surface, 4 Circulators	—	60.0 sq. ft.
Heating Surface, Firebox	235.0 sq. ft.	233.2 sq. ft.
Flues and Tubes	3 835.0 sq. ft.	3 835.0 sq. ft.
Heating Surface, Total	4 101.6 sq. ft.	4 128.2 sq. ft.
Heating Surface, Superheater	1 099.0 sq. ft.	1 099.0 sq. ft.

Boiler Pressure	225 lb.
Tractive Power	69 743 lb.
Factor of Adhesion	3.3

	Eng. 1347	Eng. 1357
Ratio, Heating Surface to Grate Area	58.2	58.6

Journals, Driving, Main	11" × 12"
Journals, Driving, Others	11" × 12"
Journals, Engine Truck	6" × 10"
Journals, Trailer	8" × 14"
Journals, Tender Truck	6" × 11"

Note:

All weights shown are the Manufacturer's estimated weights in working order.

Fig. 1.—Dimensions and other Data Regarding Engines 1347 and 1357.

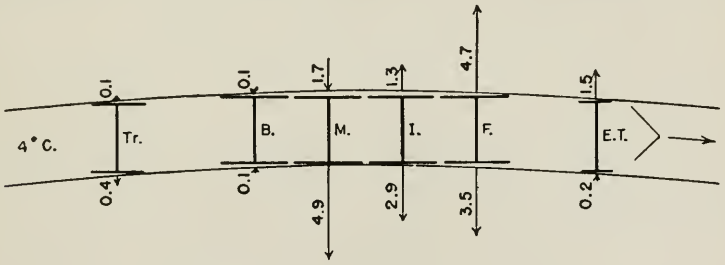
upturned leg by means of a 1-in. bolt. The magnitude of the force is determined from the flexural stress measured in the upturned leg acting as a cantilever beam. For a more detailed description of the roller bearing tie plate, see AREA Bulletin No. 447, September–October 1944, pages 69 to 72, incl., of the report covering "Counterbalance Tests of Locomotives for High Speed Service."

Electrical Strain Measuring Apparatus

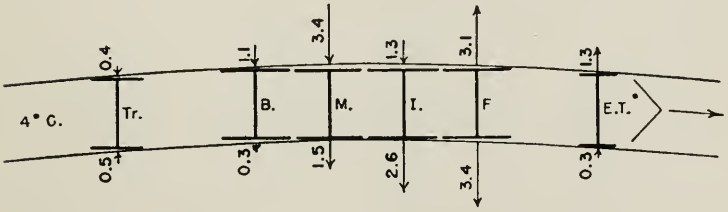
The stress measurements were made with the Baldwin–Southwark SR–4 electrical wire resistance strain gages, ½ in. in length, with the same oscillographs, electric gage amplifiers and power supplies as were used in measuring stresses in tie plates on the Southern Railway System in the summer of 1945, described in AREA Proceedings, Vol. 47, 1946, page 507. A wheel marker was used to show on the oscillograms the location of each wheel as it passed over the roller bearing tie plates.

Operation of Test Trains

Engine 1347 (modified) was tested August 12, 1946, and Engine 1357 was tested the next day. Each locomotive made three runs forward at speeds of 5, 10, 15, 20, 30 and 36 mph. with sufficient tonnage to require the maximum effort of the locomotive at the test location. The number of cars of coal hauled was varied to suit the speed desired and ranged from 50 cars (3400 actual tons) for the lower speeds to 10 cars (700 actual tons) for the highest speed. The test runs were made on approximately a 0.5-percent compensated grade ascending southward. Additional runs were made at slow speeds with the engine backing up and pushing trains down grade, and also running light in both directions.



Engine 1357 Average of 3 Runs 5.2.m.p.h.



Engine 1347 (Modified) Average of 3 Runs 5.5.m.p.h.

Fig. 2.—Engines 1347 and 1357 Hauling Trains at 5 mph.

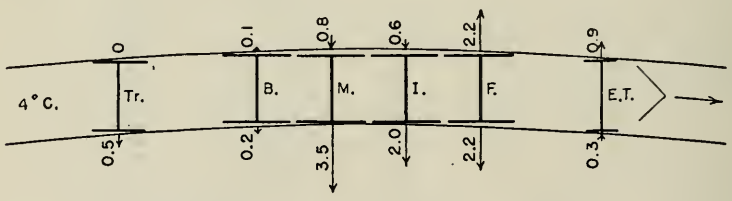
Discussion of Test Data

In these tests the lateral forces exerted on the rails by the locomotives were measured at four consecutive ties and the values used in this report are the reactions at the individual ties as each wheel passed over the four roller bearing tie plates. The lateral force diagram for a locomotive in a single test run was obtained by averaging the forces measured under each wheel as it passed over each of the four test ties. Similarly, where three runs for a locomotive were averaged, each force shown on the lateral force diagram was the average of 12 values. Therefore, the forces shown on the following diagrams are averages of the number of runs indicated, but are not simultaneous values. From a study of the simultaneous forces transmitted from one wheel to the four test ties, it was found that the total lateral force exerted by a single wheel on a rail was from 2 to 2½ times as large as the reaction measured on the tie directly under the wheel. In other words, the thrust of a wheel against a rail was distributed to three or more ties. The mean values of lateral forces measured at one tie at a time, used in this report and shown by arrows as acting from the locomotive to the rails, seem to be best suited for comparing the locomotives and determining the pattern of the lateral forces on the ties for each rail.

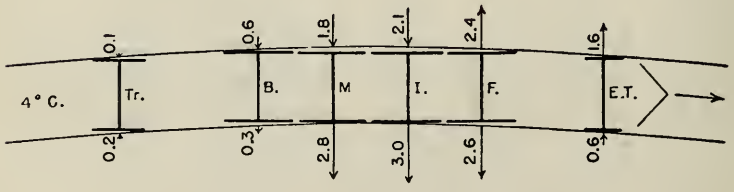
Mikado Locomotives

Fig. 2 shows the lateral force diagrams for Engines 1357 and 1347 hauling trains at 5 mph. and it will be observed that the maximum force exerted on each rail by Engine 1347 (modified) was somewhat smaller than the corresponding value for Engine 1357.

Fig. 3 is included to show the force diagrams for the two test locomotives running light at 5 mph. There are no important differences in the thrusts on the rails by the

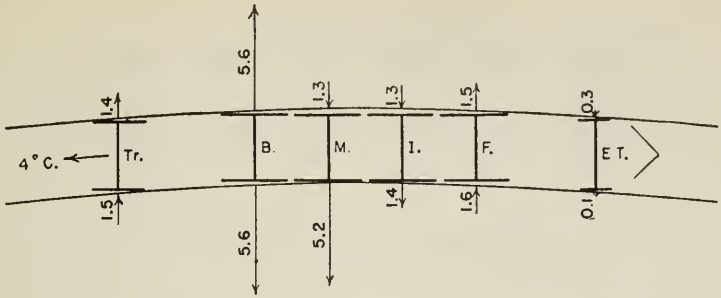


Engine 1357 Average of 2 Runs 4.8 m.p.h.

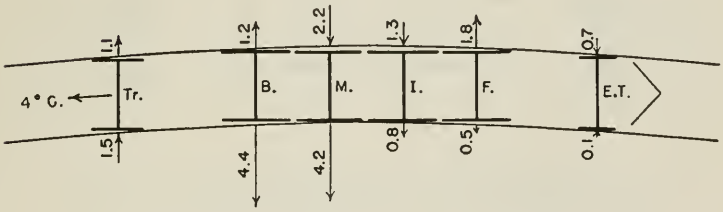


Engine 1347 (Modified) One Run 4.5 m p h.

Fig. 3.—Engines 1347 and 1357 Running Light at 5 mph.



Engine 1357 Average of 4 Runs 7.2 m.p.h.



Engine 1347 Average of 3 Runs 6.6 m.p.h.

Fig. 4.—Engines 1347 and 1357 Backing Up and Pushing Trains at 7 mph.

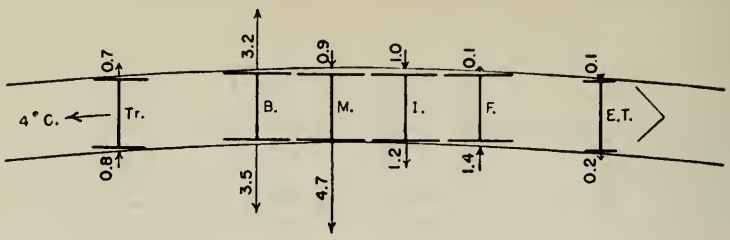
two Mikados running light. The chief purpose of the information shown in Fig. 3 is for comparison with Fig. 2 to demonstrate the differences in these forces when the locomotives were working maximum and running light at 5 mph. These differences which are relatively large in some instances can be attributed chiefly to the change in drawbar pull and serve to emphasize the variability of these lateral forces due to differences in operating a locomotive at a given speed.

Lateral force diagrams for backing up and pushing trains at slow speeds are given in Fig. 4. The maximum thrust exerted on the outer rail by Engine 1357 was considerably higher than the corresponding value for Engine 1347, while on the inner rail the difference was much less but still in favor of the latter locomotive.

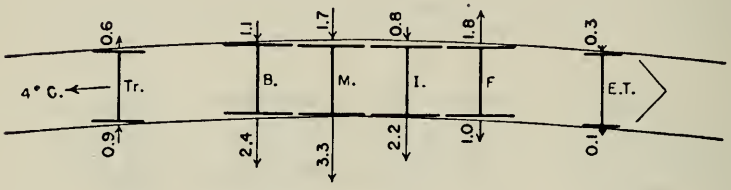
In Fig. 5 the thrusts on the rails are shown for the two locomotives making back-up light movements. In this case Engine 1357 produced moderately higher thrusts on each rail than Engine 1347. In the back-up movements the lateral forces indicate Engine 1357 was stiffer than Engine 1347.

Lateral force diagrams while hauling trains at 14 mph. are shown in Fig. 6. For this speed the differences in the maximum thrusts exerted on each rail by the two locomotives are small and the patterns of the forces are similar except for some of the smaller forces.

The thrusts exerted on the rails of the 4-deg. curve by the Mikado locomotives at their maximum speed of 36 mph. when hauling 700 actual tons are shown in Fig. 7. For these runs Engine 1357 produced a slightly higher maximum thrust on the outer

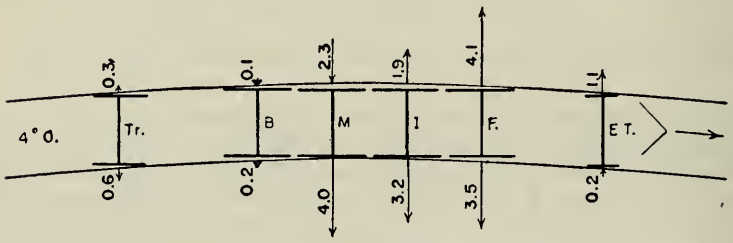


Engine 1357 One Run 3.7 m p h.

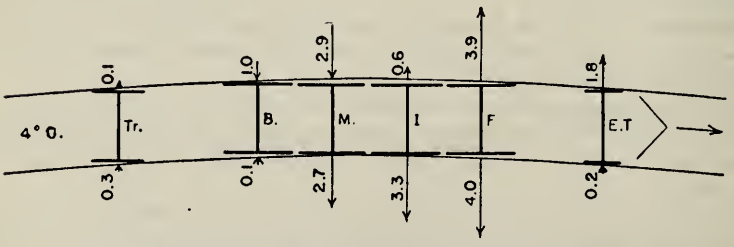


Engine 1347 One Run 5.3 m p h.

Fig. 5.—Engines 1347 and 1357 Backing Up Light at 4 mph.

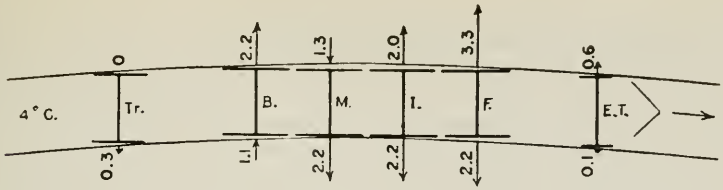


Engine 1357 Average of 3 Runs 14.3 m.p.h.

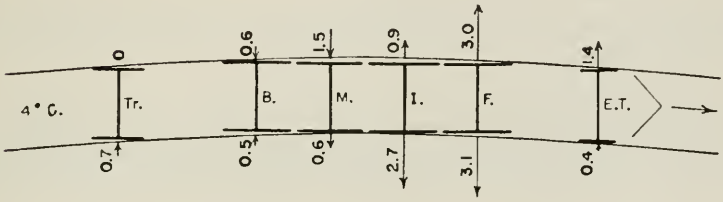


Engine 1347 (Modified) Average of 3 Runs 14.3 m p h.

Fig. 6.—Engines 1347 and 1357 Hauling Trains at 14 mph.



Engine 1357 Average of 3 Runs 35.8 m.p.h.



Engine 1347 (Modified) Average of 3 Runs 36.2 m.p.h.

Fig. 7.—Engines 1347 and 1357 Hauling Trains at 36 mph.

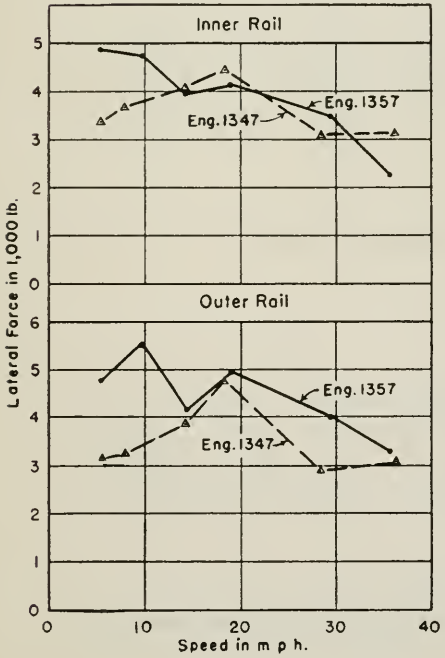


Fig. 8.—Comparison of Mean Maximum Outward Lateral Forces Exerted on the Rails of the 4-deg. Curve by Engines 1347 and 1357 Hauling Trains at Several Operating Speeds.

rail while the value for Engine 1347 was moderately higher on the inner rail. The force patterns are similar except for some of the smaller values.

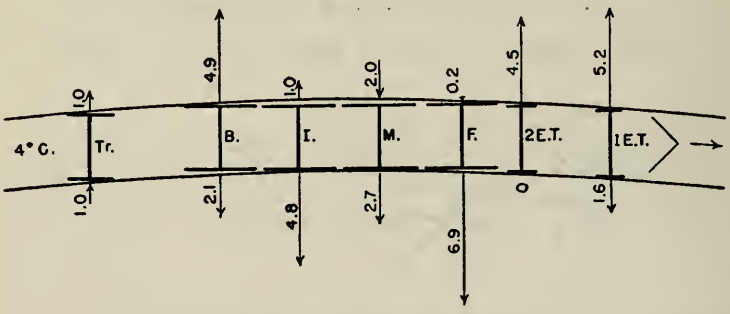
A comparison of the maximum outward thrust on each rail for the two Mikados hauling trains at speeds ranging from 5 to 36 mph. is presented in Fig. 8. Engine 1347 (modified) produced lower maximum thrusts on the outer rail over the entire range of speed. For the inner rail the values for the two locomotives were about the same from 15 to 30 mph. Below 15 mph. the effect from Engine 1347 was more favorable, and above 30 mph. Engine 1357 exerted moderately lower maximum thrusts on the inner rail. However, since the spread between the two sets of curves was never over 2000 lb. and all the maximum values were less than 6000 lb. for the two locomotives, both may be considered as subjecting the 4-deg. curved track to very moderate lateral forces. The differences in the thrusts exerted on the rails by the two locomotives are too small to warrant rating either one as being more severe on a 4-deg. curve.

Supplemental Tests of Regular Trains

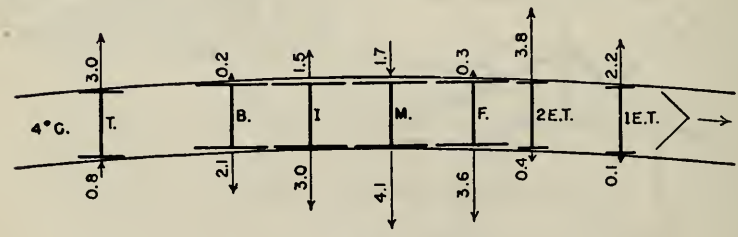
During the two-day test of the Mikado locomotives records were also taken under locomotives hauling regular passenger and freight trains.

4–8–2 Type Locomotives

Only two records were taken under this type of locomotive, one for Engine 2302 and the other for Engine 2401. These locomotives have 73½-in. drivers and a wheel base of 42 ft. 3 in. The weight in working order of Engine 2302 was 384,500 lb. and of



Run 37 Engine 2302 Running Light at 26.9 m p h.



Run 20 Engine 2401 Passenger Train No.25 36.8 m p h.

Fig. 9.—Light Engine 2302 (4–8–2) Running at 27 mph. and Engine 2401 (4–8–2) Hauling Passenger Train No. 25 at 37 mph.

Engine 2401, 362,500 lb. Both engines had lateral motion on the front drivers, slack wedge type buffers, unit type drawbars, 4-wheel Commonwealth engine trucks with coil springs and 40-percent constant resistance and 2-wheel Delta type trailing trucks with 20-percent constant resistance.

Lateral force diagrams for these two locomotives are shown in Fig. 9. Engine 2302 was running light at 27 mph. and Engine 2401 was hauling passenger train No. 25 at 37 mph. Engine 2302 produced the higher maximum thrust on both rails which was somewhat larger than that measured under the Mikados at a speed approximating 27 mph. The maximum thrusts exerted on the rails by Engine 2401 were slightly larger than those under the Mikados at the same speed. In both diagrams the guiding thrusts are exerted on the outer rail by the engine truck wheels while under the front driver the force is very small. The front drivers were relieved of the guiding because of the greater lateral clearance provided by the lateral motion device.

2–8–4 Type Locomotives

Two typical lateral force diagrams are shown in Fig. 10 for the Class 8000–8049 locomotives (2–8–4) while hauling freight trains and exerting maximum effort. These two runs were selected because the thrusts on the rails were greater than in the other runs. These locomotives were not equipped with lateral motion. They had a slack wedge type buffer with floating chafing block and a unit type drawbar. They were equipped with a 2-wheel Commonwealth engine truck fitted with Woodard constant resistance rockers providing 40 percent resistance. The trailer truck was of the 4-wheel

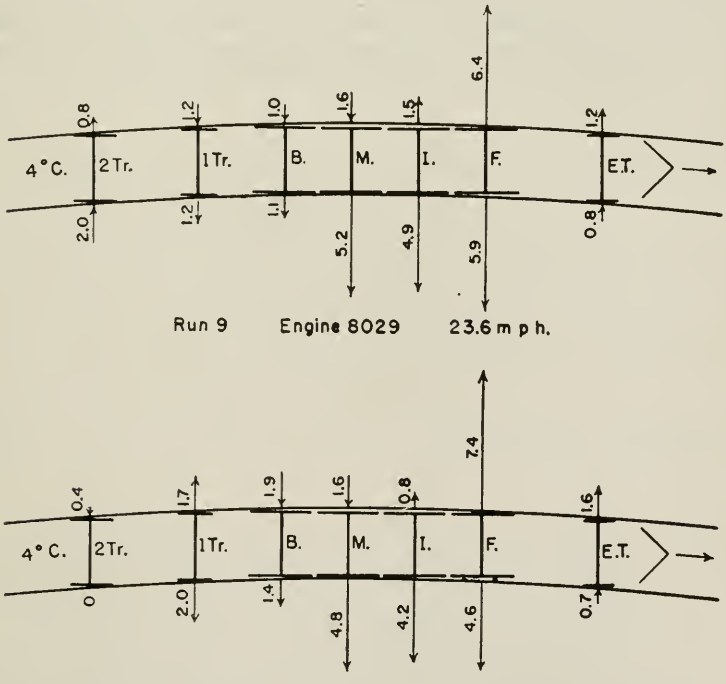


Fig. 10.—Engines 8029 and 8036 (2–8–4) Hauling Freight Trains.

articulated type with one piece cast steel frame, side bearings, constant resistance type rollers providing 14.3 percent resistance. The wheel base of these locomotives was 41 ft. 8 in. and the drivers were 63½ in. in diameter. The total weight of the engines in working order was 393,400 lb., the steam pressure 265 lb. and the tractive force, 82,100 lb.

The lateral force patterns as shown in Fig. 10 for Engines 8029 and 8036 were quite similar and the forces under all trucks were small. The largest force exerted on the rails by each locomotive was the guiding thrust on the outer rail from the front drivers. This class of engine exerted moderately higher forces on each rail than the Mikado locomotives. With this type of locomotive the front drivers performed most of the guiding.

Conclusions

The lateral forces exerted on the rails of the 4-deg. curve by the classes of power reported were very small compared to lateral forces measured in other tests. The maximum forces on the outer rail were less than half of those measured on a 10-deg. 30-min. curve. Likewise, the forces on the inner rail of the test curve were less than one-fourth of those measured on the sharper curve.

There was no significant difference in the lateral forces exerted by the Mikado type Engine 1357 with original weight distribution compared with those exerted by Engine 1347 of the same type, but with approximately 18,000 lb. more weight on its engine and trailing trucks.

Since the lateral forces exerted on the rails by the trailer trucks of the two Mikados were of comparable magnitude at the same speed, apparently on the 4-deg. curve the absence of the centering spring in the trailer of Engine 1357 had no important effect on these thrusts on the rails.

Investigation of Bridge Impacts with a Mechanical Oscillator

Description and Analysis of Tests Made on an Open Deck Truss Span

1. Digest

This report presents the results of impact tests made with a mechanical oscillator on a 102-ft. 6-in. open deck, riveted through truss bridge at Springfield, Ohio, in the spring of 1941.

The tests were designed to approximate laboratory conditions in order that damping and impact from locomotive hammer blow might be studied independently of the many indeterminate factors which contribute to the total under actual conditions. Tests were made under dead load only, and with various live loads resting on the span. The effect of various end bearing conditions was also investigated.

Stress and vertical center line deflection amplitudes were measured at various hammer blow frequencies, with different end bearing conditions, under dead load and various static live loads. Correction factors for computed stresses and deflections were obtained from measurements taken under known static live loads. Dynamic magnifiers were computed as the ratio of measured stress or deflection amplitude to the corresponding quantity calculated for a static load having a magnitude and position equal to that of the hammer blow. Stress, deflection and dynamic magnifiers are shown plotted against oscillator frequency in typical Figs. 15 to 20, incl. A summary of the results found in all the members tested is tabulated in Table 5. Fig. 21 shows the phase angle between the hammer blow and the corresponding stress plotted against the ratio of forced to natural frequency. A summary of the conclusions follows:

Damping

The damping of the span under dead load was very nearly "viscous" in nature, that is, the damping force on each element of the span was approximately proportional to the velocity of the vertical displacement of that element.

The damping constant for the test span was much less than that predicted by the 1946 AREA rating formula, indicating that values of damping computed from the results of tests under the passage of trains fail to allow for the fact that not enough hammer blows occur to cause amplitudes to build up to the maximum. In the case of oscillator tests made with locomotives or cars on the span, the results were not conclusive, but tended to show that spring friction, probably for the reason just cited, was less than the 10 to 15 percent usually considered.

Phase angle measurements were not sufficiently accurate for use in evaluating damping factors, but did tend to confirm the results obtained from dynamic magnifier curves.

Dynamic Deflection

For practical purposes the span under dead load had one node of vibration and oscillated as a single-degree of freedom system. Its configuration was adequately represented by a half sine wave.

With coal cars on the span giving a nearly symmetrical distribution of the load, the sprung weight of the cars oscillated independently of the span and the unsprung weight of the cars. The test results secured under this loading agreed closely with those predicated by theoretical means for a single two-degree of freedom system.*

* For references, consult similar figure in list of books on concluding page of this monograph.

In the case of tests made with locomotives on the span, there was wide variation between the test results and those predicted by the usual theory. Since the loading was quite unsymmetrical, it is possible that the second harmonic of the deflection curve was excited, which would account in part for the discrepancies.

Dynamic Stress

Stresses were not magnified in the same ratio as center line deflections. This was believed to be due to the inertia of the distributed mass of the bridge and its load. A method of predicting stress magnification in terms of center deflection was developed, and was found to be in fair accord with test results.

2. Foreword

The very comprehensive reports of impact tests on steel railway bridges of simple span published in Great Britain in 1928 by the Bridge Stress Committee of the Department of Scientific and Industrial Research[8] and in the United States in 1935 by the late J. B. Hunley of the New York Central Railroad[9] indicate that in most cases a reasonably good agreement between test results and theory can be expected. However, the quantitative prediction of the effect depends upon a knowledge of certain characteristic factors which cannot be determined by logical reasoning alone and must therefore be evaluated by test or estimated from the results of tests on similar structures. Among the most important of these characteristic factors is the damping inherent in the span.

All impact tests made thus far in the United States have been performed upon bridges whose motion was excited by the passage of locomotives and cars. The analysis of such tests is complicated by the presence of many unknowns whose individual effects cannot be entirely segregated. For example, the disturbing forces include locomotive hammer blow, the effect of the rolling, nosing and pitching of the live load, track effect, and speed effect; the damping includes internal hysterisis of the structure, end bearing friction, energy loss in the floor system, and journal box and spring friction losses due to oscillation of the sprung weight of the live load. Even such minor details as the sloshing about of boiler and feed water or a slight shifting of the load on a car contribute to the energy loss and thus to the damping. In enumerating the uncertainties, the lack of definite knowledge as to actual wheel loads, and the continual variation of the natural frequency of the span due to the changing position of the live load must also be considered.

In order to determine the separate effect of hammer blow and study the nature of the damping of the structure as distinguished from those characteristics imparted by the live loads, it was suggested that a series of impact tests be made using an oscillator to excite motion and taking stress and deflection records of the span under dead load and various static live loads. Such tests had been made and reported by the Bridge Stress Committee as a part of the British tests previously mentioned,[8] and an oscillator for such tests had been designed in 1938–1939 by C. T. West, a student in Ohio State University.[10]

Upon the suggestion of Mr. Hunley, then chairman of the Special Committee on Impact, the oscillator was redesigned in 1940–1941 to provide a larger motor and an easy means of adjusting the hammer blow, and to permit running in an inverted position

[8] p. 18 and Appendix H.

† Acknowledgment is made to Mr. West for his work in the preparation of this report while employed on the research staff, Engineering Division, AAR. The theoretical treatment is taken from his thesis for a master's degree at Ohio State University.

Fig. 1.—Bridge 112, Delaware Branch, Cincinnati District, New York Central Railroad, Springfield, Ohio, Viewed from Southeast.

while suspended beneath a span. Construction of the oscillator was begun by Engineering Experiment Station of Ohio State University. It soon appeared, however, that larger facilities and more funds than were there available would be required, whereupon the project was taken over by the Association of American Railroads and the oscillator completed under the supervision of E. J. Ruble, structural engineer, Engineering Division, AAR, in the Columbus, Ohio, shops of the Pennsylvania Railroad. The ownership of the oscillator is divided between the AAR (two-thirds) and the university (one-third).

Bridge 112, Delaware branch, Cincinnati district, N. Y. C. R. R., Springfield, Ohio, was chosen as the subject for the first series of tests because of its typical construction and convenient location on a light traffic branch line. Tests were begun on May 7, 1941, and completed on June 5, 1941. Analysis of the field records was begun immediately, but with the advent of war the resulting loss of available personnel, as well as the press of other work the analysis was suspended until recently.

No further oscillator tests have been made.

3. Test Equipment

Oscillator

The oscillator (Figs. 2, 3 and 4) consists basically of two identical eccentric rotors lying in the same vertical plane and turning at equal speeds in opposite directions. The rotors were geared in phase so that the vertical components of the centrifugal forces exerted by their revolving unbalanced masses were in conjunction while the horizontal components were in opposition. The rotor bearings were mounted on a stiff welded frame of wide flange beams, so that the horizontal forces were not transmitted externally. The resultant external force was then in the vertical direction and, ignoring the effect of small vertical movements of the oscillator, was a simple harmonic force. Fig. 5 is a schematic diagram of the oscillator. A similar diagram and discussion has been given by Timoshenko.[5]

[5] p. 26.

Fig. 2.—Panel Point L_2, South Truss, Showing Mechanical Deflectometer, Oscillator and Working Platforms.

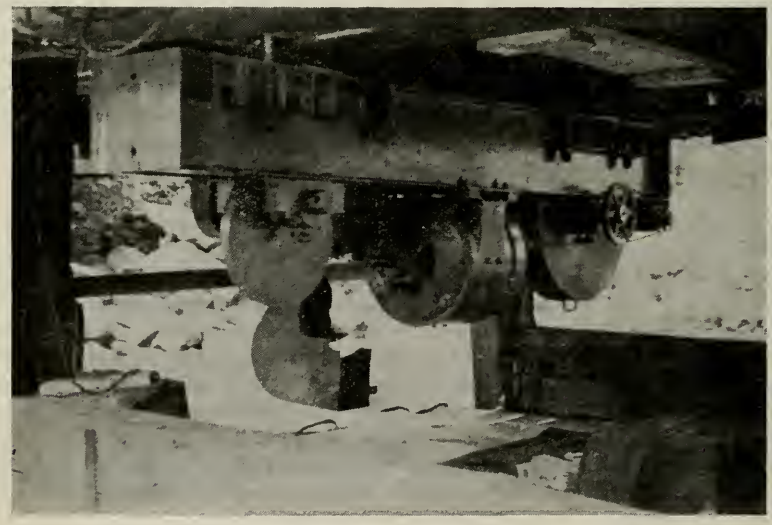


Fig. 3.—Oscillator Viewed from Southeast.

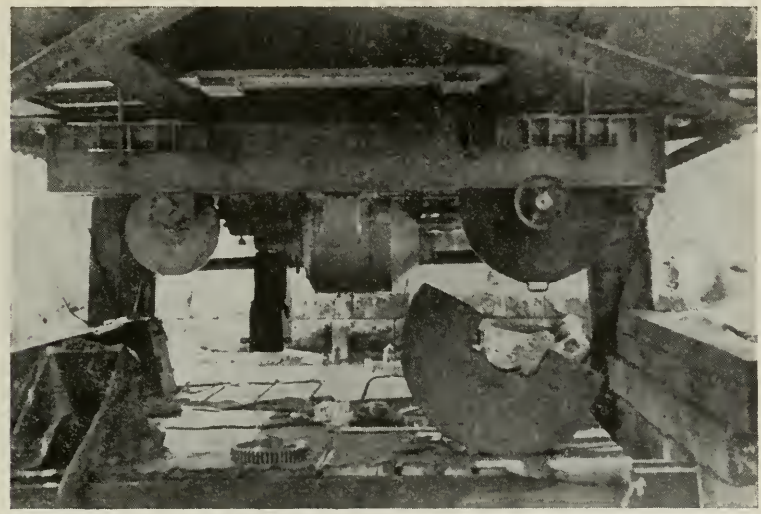
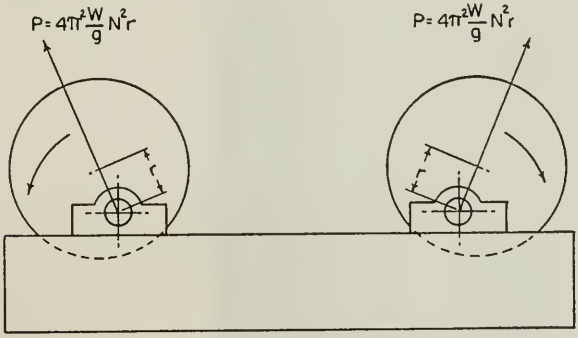


Fig. 4.—Oscillator Viewed from East. Oscillator attached directly under center floor beam. Gear housing and south rotor guard removed.



$\frac{W}{g}$ = mass of rotor

r = distance from axis of rotation to center of gravity of rotor

N = rotor speed in r.p.s.

Fig. 5.—Schematic Diagram of Oscillator.

The rotors were driven by a 15-hp. variable speed d.c. motor with power source consisting of a bank of storage batteries and a gasoline driven generator. A combination of rheostat control and gear changes provided a speed range of from 2 to 16 rps.

Variable hammer blow at a given speed was provided by constructing each rotor of three circular discs mounted eccentrically on a shaft. The outer discs were welded to the shaft while the inner disc was free to turn. A series of bolt holes through all three discs was provided so that the center disc could be turned to give the desired amount of unbalance and then be rigidly bolted in place. The hammer blow at 1 rps. could thus be varied in a series of steps from 0 to 96 lb. per rotor.

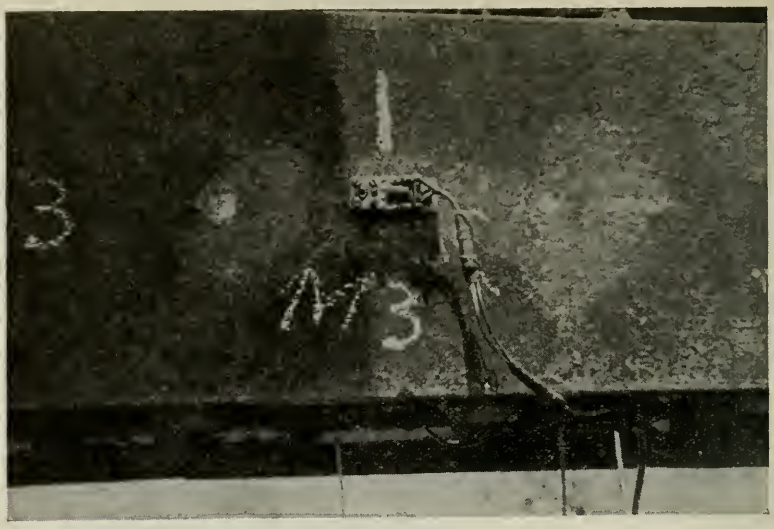


Fig. 6.—Electromagnetic Strain Gage, Neutral Axis, Member $L_1 L_2$ South Truss.

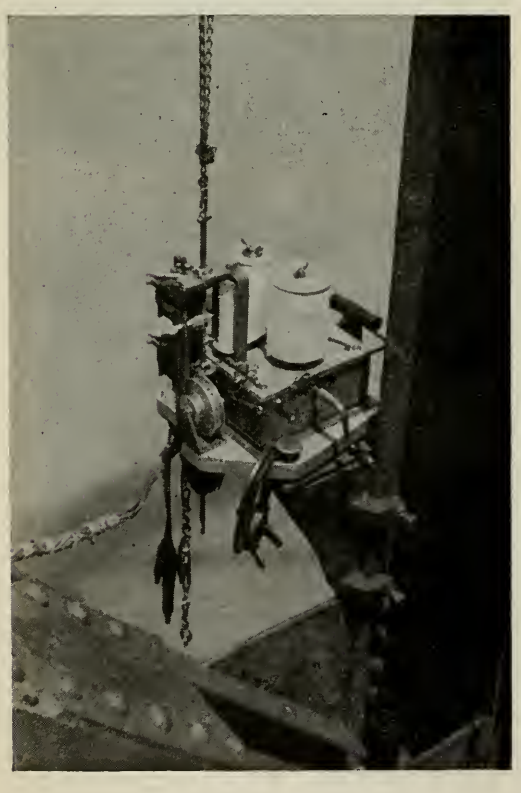


Fig. 7.—Mechanical Deflectometer, Panel Point L_2 South Truss.

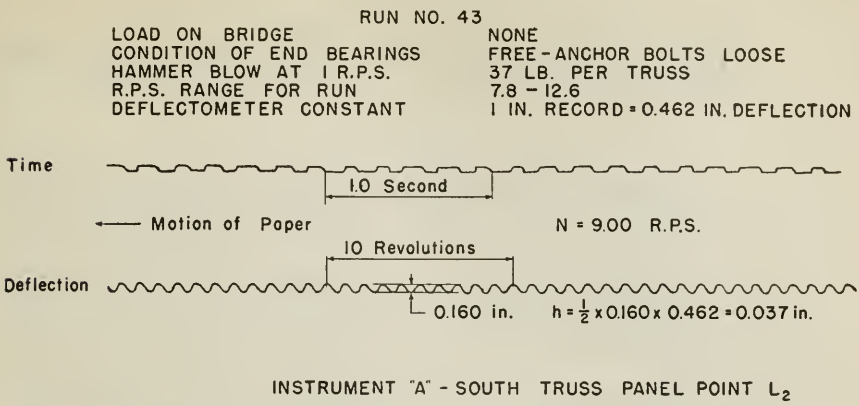


Fig. 8.—Typical Oscillator Test Record, Mechanical Deflectometers, Bridge 112.

A permanent magnet armature was mounted on the drive shaft so that once for each revolution of the rotors its flux lines cut a field coil mounted on the oscillator frame. The armature was adjusted so that with the rotors set for maximum unbalance, the peak induced electromotive force coincided with the maximum downward hammer blow on the span. By connecting the field coil to a galvanometer in the oscillograph used for recording stress measurements, and to the revolution counter solenoid of the deflectometers, the oscillator rps. could be determined without reference to the forced vibrations of the span, and the phase angle between the hammer blow and the corresponding peak stresses could be measured. (Fig. 9)

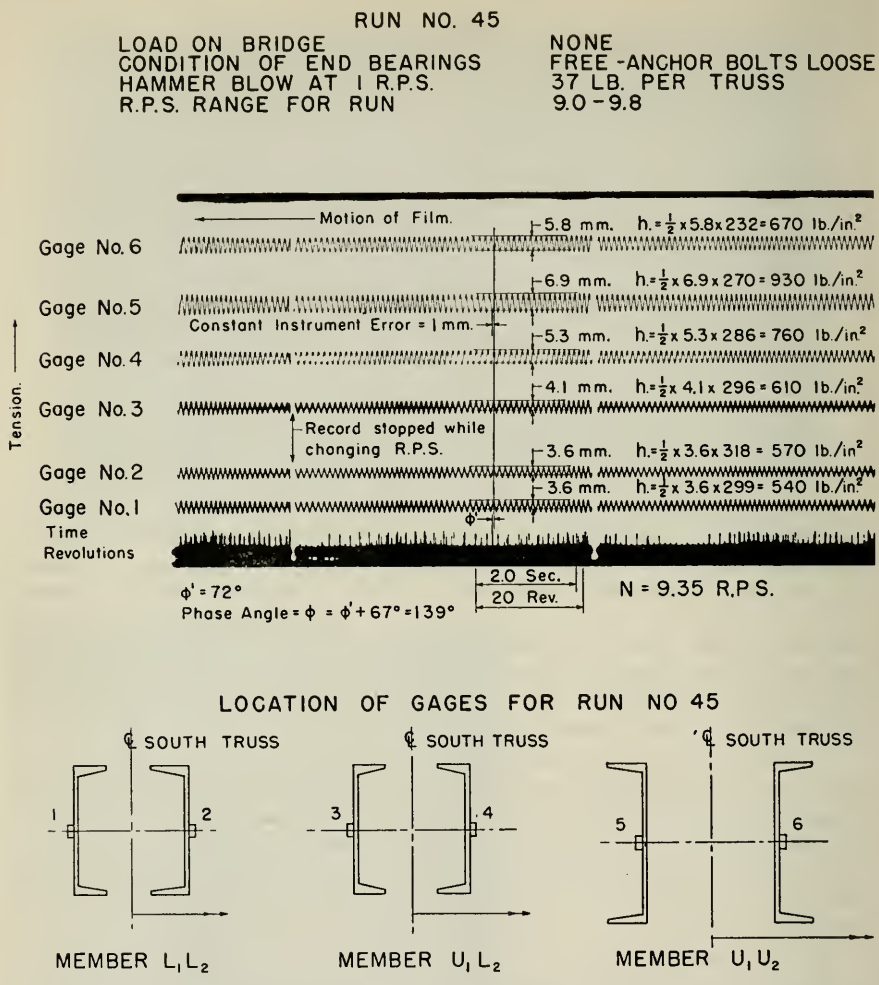
In order to deliver the hammer blow to the truss with as few indeterminate energy losses as possible, the oscillator was hung directly below the center panel floor beam, being very rigidly secured by a system of bolts, yokes and knife edges. (Fig. 11, bottom) Since the mounting was symmetrical with respect to the center line of the bridge, it was considered that each truss sustained the hammer blow from one rotor. This position of the oscillator also had the advantage of allowing a permanent set up without interference to traffic.

It is interesting to note that the British oscillator was much larger than the one just described, being capable of hammer blows at 1 rps. of up to 245 lb. per rotor, and was mounted on a bed which in turn rode on two standard car axles. The whole machine remained on the rails during the tests, the springs being blocked and the apparatus lashed to the rails with tourniquets.

Mechanical Deflectometers

A mechanical deflectometer was mounted at the center panel joint of each truss. (Figs. 2 and 7) These were the same instruments used by Mr. Hunley in his tests and are completely described as to construction and operation in his report.[9] A typical deflectometer record is shown in Fig. 8. During the run shown the revolution counter failed, making it necessary to determine the oscillator rps. from the frequency of the forced oscillations, and making it impossible to determine the phase angle. This failure was not regarded important inasmuch as the rps. were easily determined from the fre-

[9] pp. 14–16.



Gages Nos. 5 and 6 were located on Member $U_1 U_2$ as shown throughout all runs. Revolution Counter marked the downward position of Rotors at full unbalance. For reduced Hammer Blow of 37 Lb. at 1 R.P.S. the maximum downward force led the Revolution Counter by 67 Degrees.

Fig. 9.—Typical Oscillator Test Record, Electromagnetic Strain Gages, Bridge 112.

quency of oscillation as from revolution counter marks, and the phase angles measured by deflectometer were regarded unreliable because of inertia of the instrument. Amplitude and frequency would not be affected by this inertia, but the lag would increase the apparent phase angle.

The deflectometers were designed to magnify actual displacement by two, thus giving a theoretical instrument constant of 0.50. In order to correct for the stretch of the deflectometer wires, the instruments were calibrated by placing a static live load

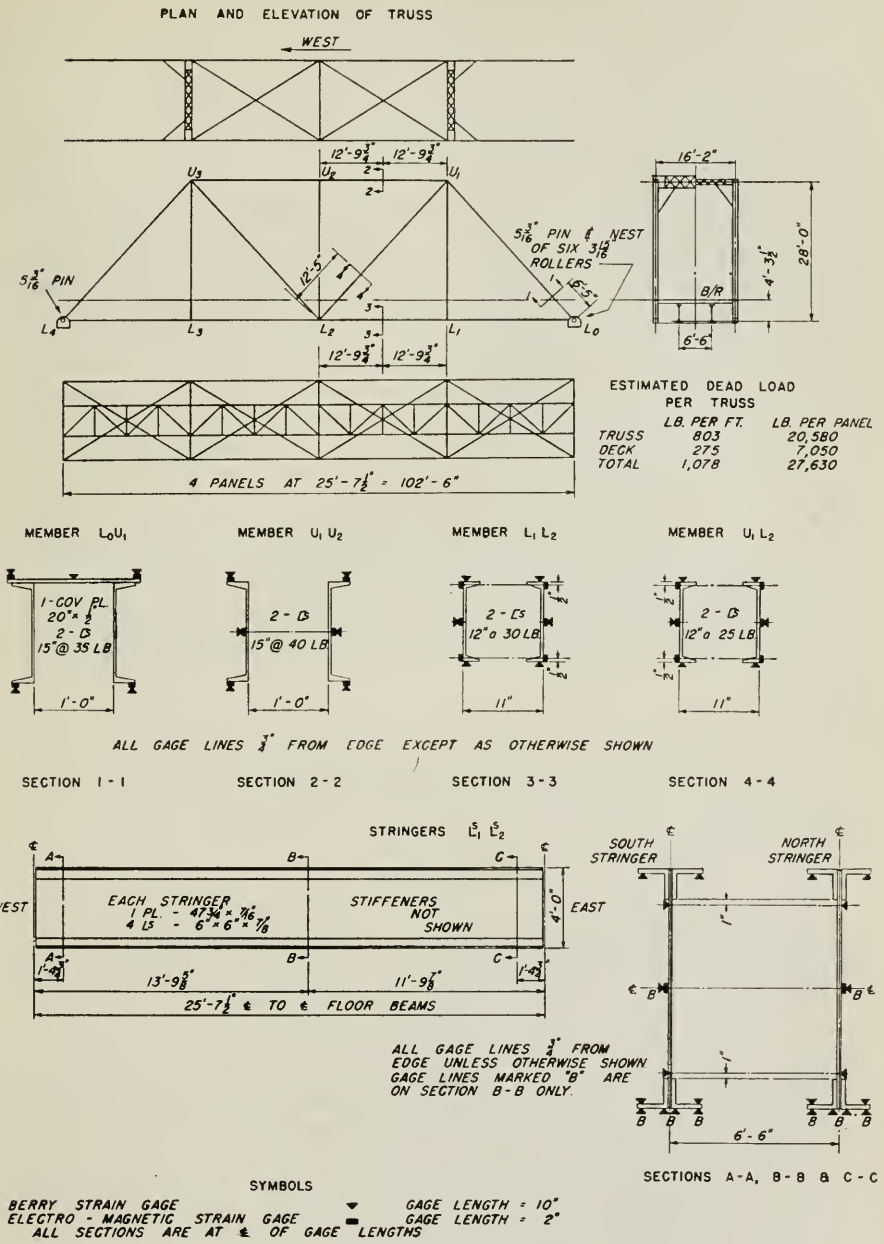


Fig. 10.—Truss Diagram and Gage Locations, Bridge 112.

on the bridge and taking deflections by the deflectometer and a wye level. The apparent deflectometer constants were then computed by the formula:

$$\text{Deflectometer constant} = \frac{\text{Deflection by levels}}{\text{Displacement of recording pencil}}$$

This constant was found to be 0.462 for both instruments.

Electromagnetic Strain Gaging Instruments

The electromagnetic strain gaging equipment was similar to that used for other tests by the Pennsylvania Railroad[11] and the Association of American Railroads.[13]

A General Electric PM–10 six-element magnetic oscillograph was used for observing and recording stresses. All electromagnetic strain gages (Fig. 6) were of 2-in. gage length. These instruments and their operation are described in the references just cited. Records were taken on either film or paper, the latter being considered more convenient.

Each strain gage was individually calibrated on its own circuit by observing the galvanometer deflections corresponding to known settings of the air gap. The gage constant for each was then determined on the basis of E = 30,000,000 psi. for the steel of the bridge. These instrument constants are shown in the sample computations for conversion of galvanometer deflection to stress on the typical strain gage record (Fig. 9).

Only south truss members L_0U_1, U_1, U_2, L_1L_2 and U_1L_2, and north and south stringer L_1^s L_2^s were strain gaged, the locations of gage lines and gage sections being shown in Fig. 10. Gages 5 and 6 were attached at the neutral axis of member U_1 U_2 for all tests, while the others were shifted from member to member in accordance with the test schedule. Since member L_0 U_1 was nonsymmetrical, four gages were always used when testing it, two being located on the top surface and two on the bottom as shown in Fig. 10.

Berry Strain Gages

Standard Berry strain gages of 10-in. gage length were used to measure static live load stresses as a check on the accuracy of similar determinations made with the electromagnetic gages. The locations of the Berry gage lines and sections are also shown in Fig. 10.

4. Test Span

Bridge 112 is a single-track, open-floor, high through truss span, 102 ft. 6 in. in length. The dimensions, major details, and weight are shown in Fig. 10. Figs. 1, 2 and 11 (bottom) may be referred to for additional details. A summary of computed theoretical stresses and deflections for unit panel loads and for the dead load is given in Table 1.

All joints were riveted except at panel points L_0 and L_4 where a single pin connected the end posts and lower chord members to each other and to the bridge shoes. The general construction of the span, especially of the floor system, is quite stiff. All floor beams and stringers were deep, rigidly connected members, and the end floor beams were stiffly gusseted to the end posts. That the stringers carried over half of the total lower chord static tension was evident from the low value (0.440) obtained experimentally for the lower chord stress factor. The shoes at the west end of each truss were bolted to the abutment. At the east end, the shoes rested on nests of rollers, which in turn were bolted to the masonry.

Except for tightly rusted end bearings and roller nests, and a few badly corroded top lateral system members, the steel work was in excellent condition. Measurements showed the track well centered on the span so that no correction for eccentricity of the

TABLE 1.—CALCULATED STRESSES AND DEFLECTIONS

LOADING PER TRUSS	STRESS IN MEMBER - KIPS PER SQ. IN. (+) INDICATES TENSION							DEFLECTION - INCHES		
	$L_0 U_1$	$U_1 U_2$	$L_0 L_1$	$L_1 L_2$	$U_1 L_1$	$U_1 L_2$	$U_2 L_2$	PANEL POINT L_1	PANEL POINT L_2	PANEL POINT L_3
Col.1	Col.2	Col.3	Col.4	Col.5	Col.6	Col.7	Col.8	Col.9	Col.10	Col.11
1000 LB. AT L_1	(-) 0.03338	(-) 0.01956	(+) 0.03904	(+) 0.03904	(+) 0.05123	(-) 0.02315	0	0.002036	0.001313	0.000893
1000 LB. AT L_2	(-) 0.02225	(-) 0.03911	(+) 0.02603	(+) 0.02603	0	(+) 0.04630	0	0.001313	0.002633	0.001313
1000 LB. AT L_3	(-) 0.01113	(-) 0.01956	(+) 0.01301	(+) 0.01301	0	(+) 0.02315	0	0.000893	0.001313	0.002036
DEAD LOAD 27,650 LB. PER PANEL + 2000 LB. OSCILLATOR AT L_2	(-) 1.889	(-) 2.239	(+) 2.209	(+) 2.209	(+) 1.415	(+) 1.372	0	0.1198	0.1506	0.1198

static live load was required. Before commencing tests the track was reconditioned by replacing decayed ties and tightening track bolts, hook bolts and spikes.

Level readings were made to determine the settlement of the end panel points under static live loads. The following deflections were observed:

	Panel Point L_0	*Panel Point* L_4
South truss (Locomotive 2244)	0.03 in.	0.05 in.
North truss (Locomotive 2216)	0.02 in.	0.06 in.

Inasmuch as the masonry was in a fairly good state of repair it is believed that the settlement was attributable to subsurface conditions.

5. Test Locomotives and Cars

Test locomotives and cars of known weight were used for the determination of static stress and deflection factors. The same locomotives and cars were also in position on the span during some of the oscillator tests in order that the effect of such live loads on impact might be studied.

Fig. 11 is a diagram showing the positions, wheel loads, wheel spacing, and panel point reactions of the live loads used for this purpose. Table 6 shows the wheel loads and panel point reactions broken down in terms of sprung and unsprung weight.

6. General Test Procedure

The preliminary work consisted of securing the oscillator to the truss, erecting the test house, battery and working platforms, setting up the oscillograph, a.c. generator, batteries, d.c. battery charging generator, oscillator control box and power lines, and laying out, drilling and tapping gage points. All electromagnetic strain gages were then calibrated and installed, and the deflectometers were installed on the trusses.

For purpose of comparison and determination of stress and deflection factors, static test loads were placed on the span, stresses were measured by both Berry and electromagnetic gages, and deflections were taken by level and deflectometer. Berry gage measurements were made on all gage lines, but since only six electromagnetic gages were available, the symmetrical members $U_1 U_2$, $L_1 L_2$, and $U_1 L_2$ were electrically gaged only

TABLE 2.—COMPARISON OF MEASURED AND CALCULATED STATIC LIVE LOAD STRESSES

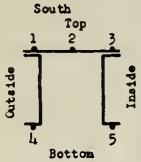
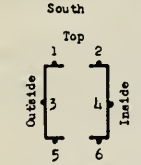
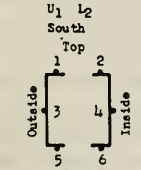
MEMBER	LOAD ON BRIDGE	BERRY GAGES							PERCENT MAXIMUM OVER AVG.
		GAGE POSITION	STRESS	AVERAGE STRESS					
				TOP	BOTTOM	OUTSIDE	INSIDE	SECTION	
Col.1	Col.2	Col.3	Col.4	Col.5	Col.6	Col.7	Col.8	Col.9	Col.10
L_0 U_1 South 	Engine No. 2216	1 2 3 4 5	3540 4680 7080 7300 8320	5100	7810	5420	7700	6460	29
	Coal Cars	1 2 3 4 5	1860 2820 3540 4620 5280	2740	4950	3240	4410	3850	37
U_1 U_2 South	Engine No. 2216	1 2 3 4 5 6	9120 7860 7980 6900 7020 6060	8490	6540	8040	6940	7490	22
	Engine No. 2216								
	Engine No. 2214	1 2 3 4 5 6	8640 7320 7020 5820 5400 5040	7980	5220	7020	6060	6540	32
	Engine No. 2214	1 2 3 4 5 6	9480 8280 8460 7680 7320 6360	8860	6840	8420	7440	7930	20
	Coal Cars	1 2 3 4 5 6	5400 5100 4080 3900 4440 3660	5250	3900	4540	4220	4380	23
L_1 L_2 South 	Engine No. 2216								
	Engine No. 2214	1 2 3 4 5 6	3480 3660 3480 3420 3420 3240	3570	3330	3460	3440	3450	6
	Engine No. 2214	1 2 3 4 5 6	3120 2640 3180 2760 3240 2940	2880	3090	3180	2780	2980	9
U_1 L_2 South 	Engine No. 2214	1 2 3 4 5 6	6240 6480 5580 6360 6960 7200	6360	7080	6260	6680	6470	11

TABLE 2.—(Continued) COMPARISON OF MEASURED AND CALCULATED STATIC LIVE LOAD STRESSES

ELECTROMAGNETIC GAGES						CALCULATED				
GAGE POSITION	STRESS	AVERAGE STRESS			PERCENT MAXIMUM OVER AVG.	TOP	BOTTOM	AVERAGE FOR SECTION	DIRECT STRESS THRUST ÷ AREA	PERCENT MAXIMUM OVER AVG.
		TOP	BOTTOM	SECTION						
Col.11	Col.12	Col.13	Col.14	Col.15	Col.16	Col.17	Col.18	Col.19	Col.20	Col.21
1 3 4 5	3590 6250 7640 9460	4920	8550	6740	40	4080	9350	6720	5930	39
1 3 4 5	1610 3240 3940 4950	2420	4450	3440	44	2080	4780	3430	3030	39
3 4	8540 7260			7900	8	7420	6920	7170	7170	4
3 4	8620 7440			8030	7	7420	6920	7170	7170	4
3 4	8120 6920			7520	8	7270	6770	7020	7020	4
3 4	7840 6960			7400	6	7270	6770	7020	7020	4
3 4	4350 3970			4160	5	3900	3640	3770	3770	4
3 4	3170 2900			3040	4	6960	6900	6930	6930	0
3 4	2990 3180			3090	3	6740	6700	6720	6720	0
3 4	2790 2840			2820	1	6740	6700	6720	6720	0
3 4	5080 6800			5940	15	4680	4660	4670	4670	0

A

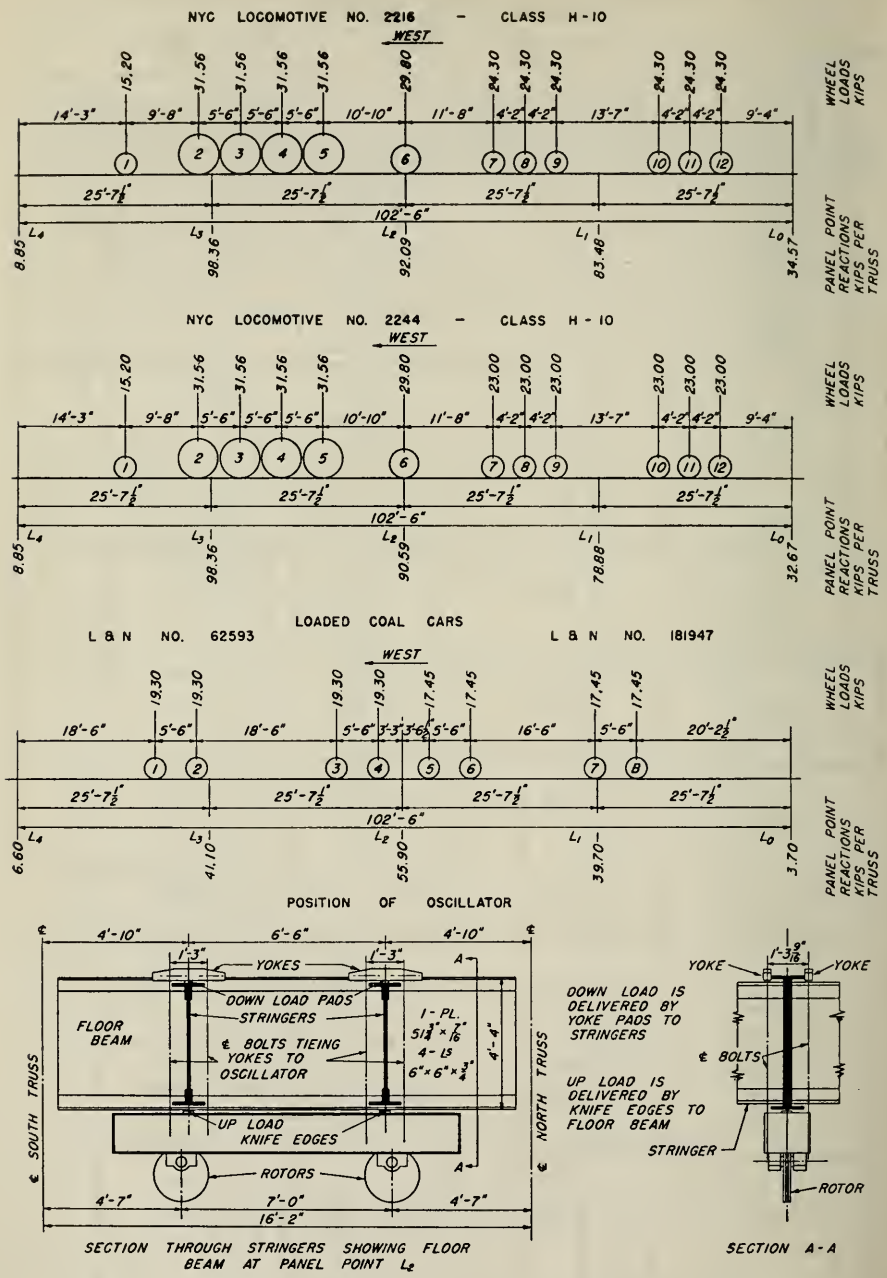

NYC LOCOMOTIVE NO. 2216 – CLASS H-10
WEST
15.20 31.56 31.56 31.56 31.56 29.80 24.30 24.30 24.30 24.30 24.30 24.30
WHEEL LOADS KIPS
14'-3" 9'-8" 5'-6" 5'-6" 5'-6" 10'-10" 11'-8" 4'-2" 4'-2" 13'-7" 4'-2" 4'-2" 9'-4"
1 2 3 4 5 6 7 8 9 10 11 12
25'-7½" 25'-7½" 25'-7½" 25'-7½"
102'-6"
L4 L3 L2 L1 L0
8.85 98.36 92.09 83.48 34.57
PANEL POINT REACTIONS KIPS PER TRUSS
NYC LOCOMOTIVE NO. 2244 – CLASS H-10
WEST
15.20 31.56 31.56 31.56 31.56 29.80 23.00 23.00 23.00 23.00 23.00 23.00
WHEEL LOADS KIPS
14'-3" 9'-8" 5'-6" 5'-6" 5'-6" 10'-10" 11'-8" 4'-2" 4'-2" 13'-7" 4'-2" 4'-2" 9'-4"
1 2 3 4 5 6 7 8 9 10 11 12
25'-7½" 25'-7½" 25'-7½" 25'-7½"
102'-6"
L4 L3 L2 L1 L0
8.85 98.36 90.59 78.88 32.67
PANEL POINT REACTIONS KIPS PER TRUSS
LOADED COAL CARS
L & N NO. 62593
L & N NO. 181947
WEST
19.30 19.30 19.30 19.30 17.45 17.45 17.45 17.45
WHEEL LOADS KIPS
18'-6" 5'-6" 18'-6" 5'-6" 3'-3" 3'-6" 5'-6" 16'-6" 5'-6" 20'-2½"
1 2 3 4 5 6 7 8
25'-7½" 25'-7½" 25'-7½" 25'-7½"
102'-6"
L4 L3 L2 L1 L0
6.60 41.10 55.90 39.70 3.70
PANEL POINT REACTIONS KIPS PER TRUSS
POSITION OF OSCILLATOR
4'-10" 6'-6" 4'-10"
1'-3" 1'-3"
YOKES
A
DOWN LOAD PADS
STRINGERS
FLOOR BEAM
℄ BOLTS TIEING YOKES TO OSCILLATOR
1 - PL. 5¼" × 7/16"
4 - L5 6" × 6" × ¾"
4'-4"
UP LOAD KNIFE EDGES
ROTORS
4'-7" 7'-0" 4'-7"
16'-2"
℄ SOUTH TRUSS
℄ NORTH TRUSS
SECTION THROUGH STRINGERS SHOWING FLOOR BEAM AT PANEL POINT L2
YOKE
1'-3 9/16"
YOKE
DOWN LOAD IS DELIVERED BY YOKE PADS TO STRINGERS
℄ BOLTS
UP LOAD IS DELIVERED BY KNIFE EDGES TO FLOOR BEAM
STRINGER
ROTOR
SECTION A-A

Fig. 11.—Test Locomotive and Test Car Data, Position of Oscillator.

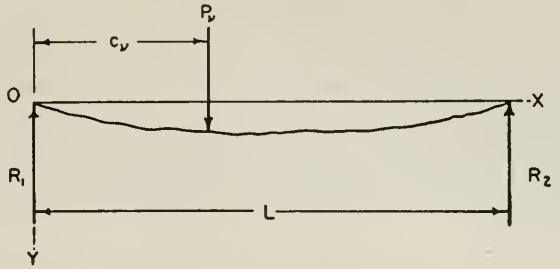


Fig. 12.—Coordinate System for Oscillations of Uniform Beam.

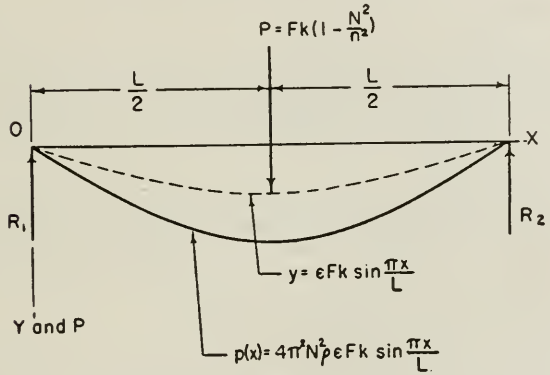


Fig. 13.—Distribution of Dynamic Loads on Span.

on their neutral axes, while the nonsymmetrical member L_0 U_1 was gaged on the top and bottom extreme fibers. Stresses were measured only on south truss members and both north and south stringers $L_1{}^sL_2{}^s$, while deflections were measured on both trusses. Table 2 gives the measured and computed static live load stresess, and Table 4 gives the corresponding deflections. Fig. 14 shows the static stress distribution over the member cross sections as determined from Berry gage readings.

Sixty-one oscillator test runs were made for record. The oscillator speed was varied during every run, each speed being held constant for from 15 to 30 sec. to allow the transient vibrations to die out. Thus for practical purposes the records consisted only of steady forced vibrations. An average of about ten speed increments made up each run.

Tests were made under dead load and various static live loads with the bridge pins and rollers badly corroded. In this condition there was no observed motion at the bearings. After the pins were lubricated, the roller nests cleaned, and the rollers renewed, a second series of dead load oscillator tests was made with the bearings functioning properly. All live load tests were made with the bearings frozen. Gages 1 to 4 were shifted among the various members so that representative stress measurements were secured on all members tested.

Various degrees of oscillator unbalance were used. A hammer blow of 37 lb. per rotor at 1 rps. gave satisfactory amplitudes for the dead load tests and in the neighborhood of the second critical frequency for the live load tests, these frequencies being not less than about 9 rps. The maximum hammer blow available, 96 lb. per rotor at 1 rps., was barely sufficient to give satisfactory results in the neighborhood of the locomotive live load lower critical frequency which was approximately 3.7 rps.

The oscillator power input was measured, but was found to be erratic and highly dependent upon the rotor bearing temperatures, and for that reason was not used in evaluating the damping.

Before any test records were made, it was necessary to tie down the top lateral angles to keep them from vibrating excessively which would have introduced additional damping.

7. Analysis of Field Test Records

Reading of Records

Figs. 8 and 9 represent typical deflectometer and strain gage test records.

Since no oscillator tests were made under moving live loads there was no need to establish static live load stress and deflection lines on the records. Analyses were made at points where it was evident that amplitude and frequency had remained practically constant for several seconds.

The first step in reducing a stress record was to draw the envelope of each curve. Because of the width of the lines, both tangents were drawn to the same side of the curve. The distance a in millimeters between envelope lines was measured, this representing the double amplitude of the stress oscillation, and the corresponding semiamplitude of stress was computed by the formula:

$$h = \tfrac{1}{2} \times a \times (\text{gage constant}) \quad \ldots\ldots (1)$$

The next step was to determine the hammer blow frequency, for which an average value over a suitable interval, usually 2 sec., was used. The distance β_1 between time marks 2 sec. apart, and the distance β_2 between 20 successive revolution counter marks were measured, and the frequency computed by the formula:

$$N = \frac{10\beta_1}{\beta_2} \quad \ldots\ldots (2)$$

The phase angle ϕ by which the hammer blow led the stress was determined indirectly. The distance γ_1 between two successive marks of the revolution counter, and the distance γ_2 between the first mark of the revolution counter and the subsequent maximum compression at gage number 6 were measured. Then ϕ', the phase angle between a revolution counter mark and the maximum stress, was computed by the formula:

$$\phi' = \frac{360 \text{ deg.} \gamma_2}{\gamma_1} \quad \ldots\ldots (3)$$

Since the counter mark indicated the time of maximum downward hammer blow with the rotors set for maximum unbalance, a correction was necessary to obtain ϕ when the other rotor settings were used. For a hammer blow at 1 rps. of 37 lb. per rotor, the correction was 67 deg., and

$$\phi = \phi' + 67 \text{ deg.} \quad \ldots\ldots (4)$$

As can be seen from Fig. 9, ϕ could not be accurately determined because large phase angles were represented by very small displacements on the record.

The reduction of the deflectometer records was accomplished by a like procedure. Here, however, the revolution counter recording solenoid failed so consistently that frequency was measured on the basis of the distance between oscillation peaks. Since forced oscillations occur at the frequency of the disturbing force this procedure was valid. No attempt was made to measure phase angles by the deflectometer because it was felt that the mechanical inertia of the recording mechanism would introduce too great an error.

Stress and Deflection Corrections

No correction was made for the distance of 0.44 in. from the center of gravity of the air gaps of the electromagnetic gages to the gage surfaces of the members, since this effect was automatically eliminated in averaging the stresses over the cross sections. The deflectometer constants, obtained by the procedure described above, contained all necessary corrections, including an average allowance for wire stretch.

Correction factors for application to computed stresses were found by comparing the average measured static live load stresses with the corresponding computed values. In arriving at these factors, only electromagnetic gage measurements were used inasmuch as these were the instruments used in measuring the dynamic stresses. Table 2 gives the calculated and measured values of the stress at various gage lines. The average of the measured stresses over the cross section of each member, the calculated unit stress resulting from axial load alone and the stress factors are given in Table 3. Fig. 14 shows graphically the static stress distribution over each member cross section as determined from Berry gage readings.

It should be noted that for the nonsymmetrical member $L_0\ U_1$ the mean of the measured stresses was not theoretically equal to the axial load divided by the cross section area, except in the unlikely event of zero moment at the gage section. Since the pin at L_0 was located at the center line of the channels, 2.54 in. below the neutral axis, there was an inherent moment due to eccentric application of the axial load. The effect on all members of this moment was determined by the Cross* moment distribution method and is included in the calculated stresses of Table 2. No other secondary stresses were considered. It is evident the stress factor for $L_0\ U_1$ includes the correction for the effect of all moments existing under the test load, and for any change of moment proportional to the change in axial load.

Deflection factors were similarly found by a comparison of deflectometer results with calculated values. These quantities are given in Table 4, the values obtained under locomotive loads being the ones used in reducing the data.

Computation of Dynamic Magnifiers

Let h be the measured semi-amplitude of oscillation produced by a harmonic force $F \sin 2\pi Nt$. Let d be the displacement which would result from the static application of a force F at the same point. Then, for the purpose of preliminary analysis of data, the dynamic magnifier was defined as:

$$k = \frac{h}{d} \qquad (5)$$

Here h and d may represent either deflection or stress; k is, of course, a pure number. (Insofar as stress is concerned, this definition will later be modified.)

* Continuous Frames of Reinforced Concrete, by Cross and Morgan.

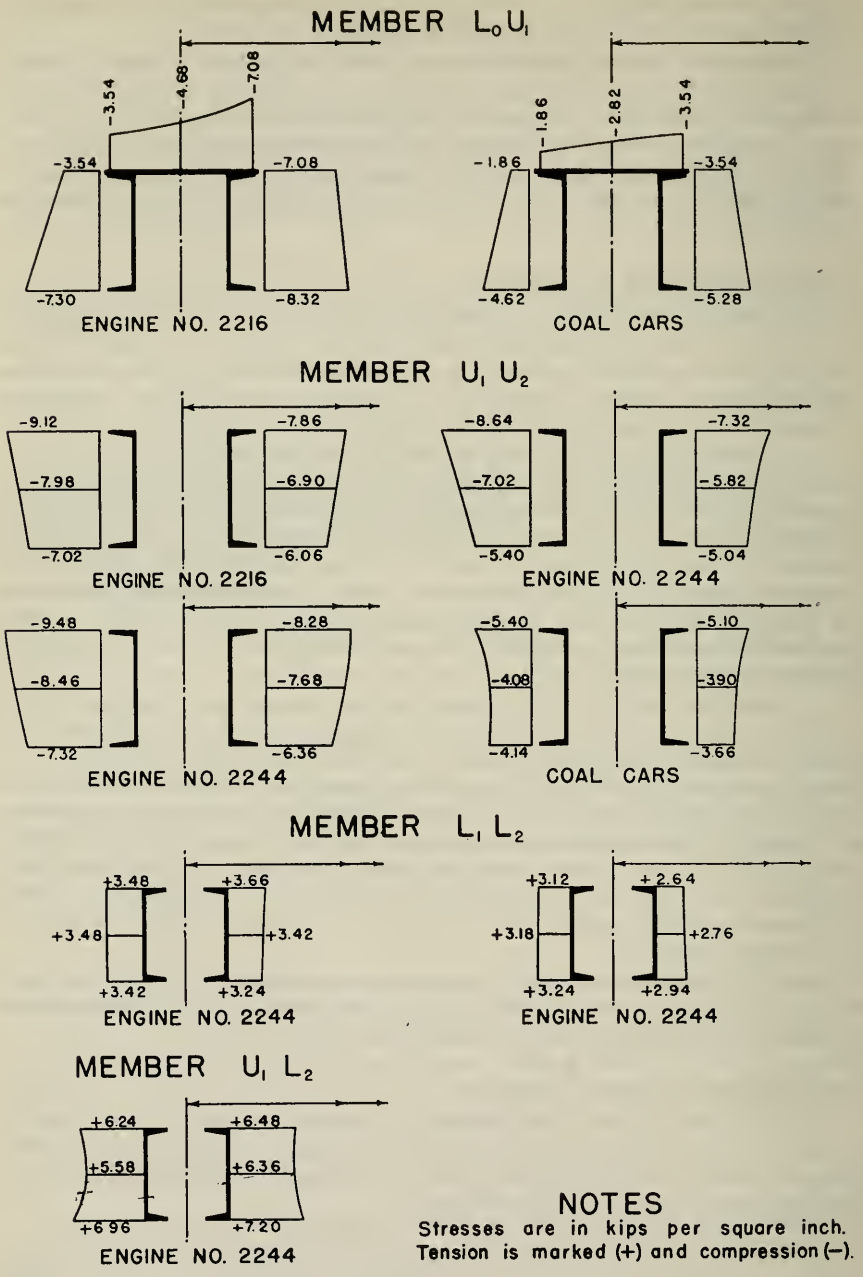


Fig. 14.—Stress Distribution over Member Sections, Berry Gage Readings, Bridge 112.

TABLE 3.—SUMMARY COMPARISON OF AVERAGE MEASURED AND CALCULATED LIVE LOAD STRESSES

MEMBER	LOAD ON BRIDGE	AVG. MEASURED STATIC STRESS LB. PER SQ.IN.		CALCULATED STATIC STRESS LB. PER SQ.IN.	STRESS FACTOR MEASURED ÷ CALCULATED		AVERAGE STRESS FACTOR BY
		BERRY GAGES	ELECTRO-MAGNETIC GAGES		BERRY GAGES	ELECTRO-MAGNETIC GAGES	ELECTRO-MAGNETIC GAGES
Col.1	Col.2	Col.3	Col.4	Col.5	Col.6	Col.7	Col.8
L_0 U_1 South Truss	Engine No.2216	6460	6740	5930	1.09	1.14	1.14
	Engine No.2244			5750			
	Coal Cars	3850	3440	3030	1.27	1.14	
U_1 U_2 South Truss	Engine No.2216	7490	7960	7170	1.04	1.11	1.09
	Engine No.2244	7230	7460	7020	1.03	1.06	
	Coal Cars	4380	4160	3770	1.16	1.10	
L_1 L_2 South Truss	Engine No.2216		3040	6930		0.439	0.440
	Engine No.2244	3220	2960	6720	0.478	0.441	
	Coal Cars			3540			
U_1 L_2 South Truss	Engine No.2216			4630			1.27
	Engine No.2244	6470	5940	4670	1.38	1.27	
	Coal Cars			2620			

TABLE 4.—COMPARISON OF MEASURED AND CALCULATED STATIC LIVE LOAD DEFLECTIONS

LOAD ON BRIDGE	℄ MEASURED DEFLECTION = d_m		℄ CALCULATED DEFLECTION = d_c		DEFLECTION FACTOR = $d_m \div d_c$	
	SOUTH TRUSS	NORTH TRUSS	SOUTH TRUSS	NORTH TRUSS	SOUTH TRUSS	NORTH TRUSS
Col.1	Col.2	Col.3	Col.4	Col.5	Col.6	Col.7
ENGINE NO.2216		0.410	0.482	0.482		0.852
ENGINE NO.2244	0.370		0.472	0.472	0.784	
COAL CARS	0.200	0.200	0.253	0.253	0.790	0.790

Experimental values of k were determined from the tests by the above formula. The semi-amplitude h and the frequency N were taken from the test records. Using the known hammer blow per rotor at 1 rps., the corresponding displacement D_h was computed, applying in the process the appropriate stress or deflection factor. Then $d = D_h N^2$, and the formula for k became:

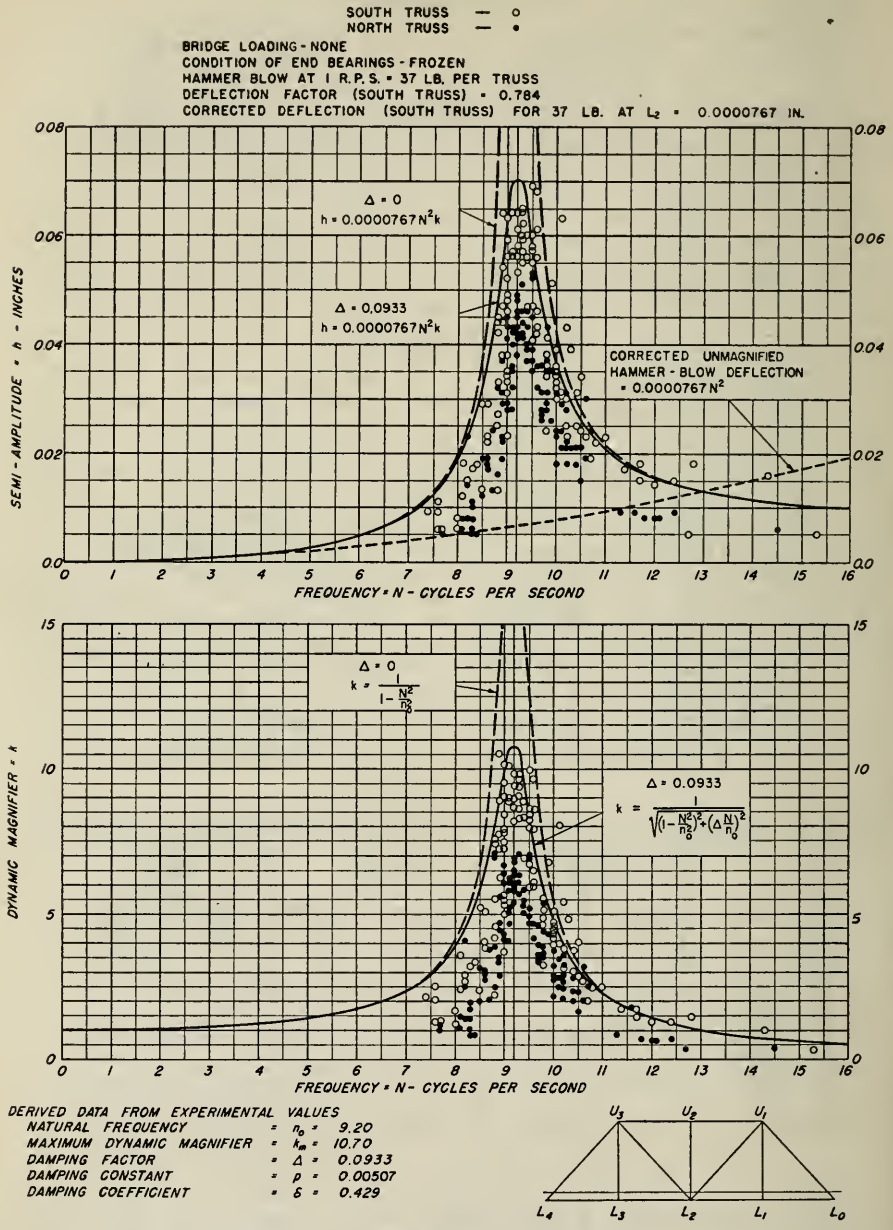
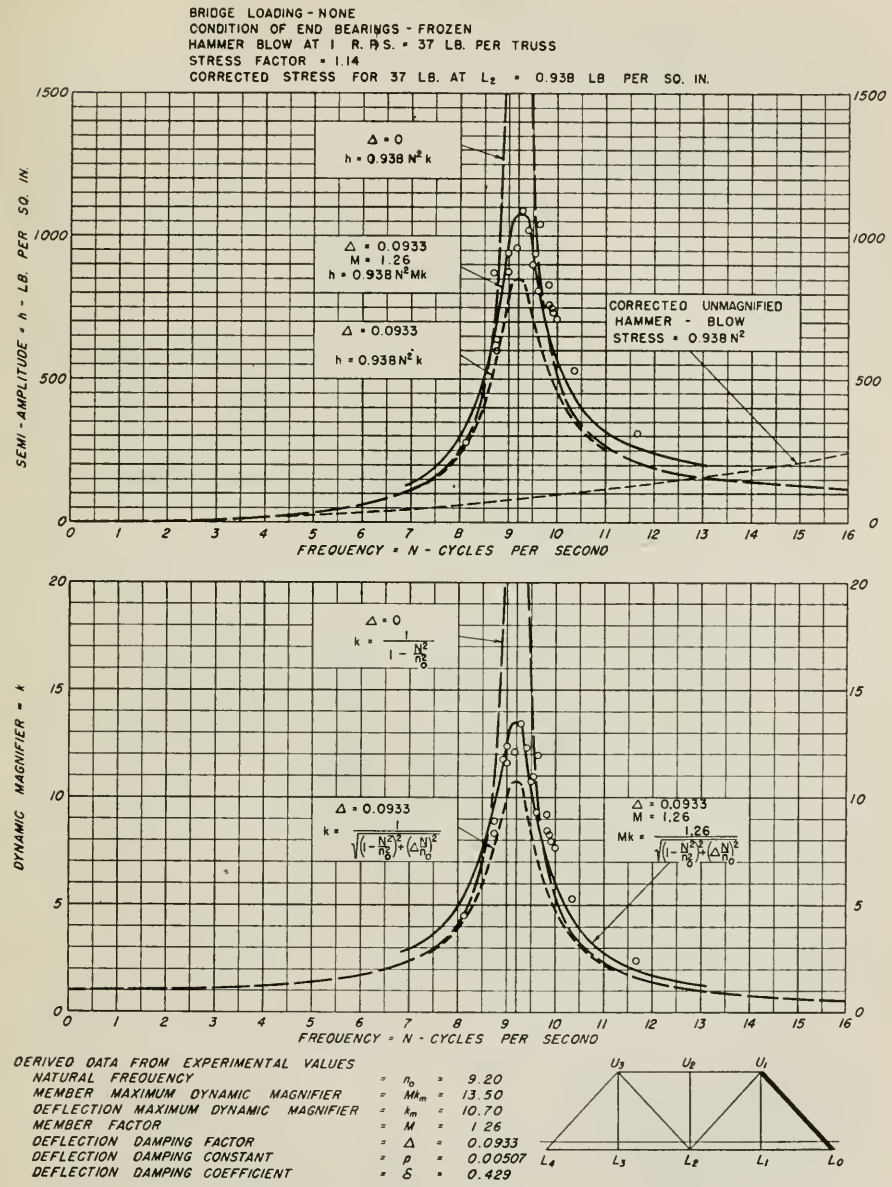

SOUTH TRUSS — o
NORTH TRUSS — •
BRIDGE LOADING - NONE
CONDITION OF END BEARINGS - FROZEN
HAMMER BLOW AT 1 R.P.S. = 37 LB. PER TRUSS
DEFLECTION FACTOR (SOUTH TRUSS) = 0.784
CORRECTED DEFLECTION (SOUTH TRUSS) FOR 37 LB. AT L2 = 0.0000767 IN.
Δ = 0
h = 0.0000767N²k
Δ = 0.0933
h = 0.0000767N²k
CORRECTED UNMAGNIFIED HAMMER - BLOW DEFLECTION = 0.0000767N²
SEMI - AMPLITUDE = h - INCHES
FREQUENCY = N - CYCLES PER SECOND
Δ = 0
k = 1 / (1 − N²/n₀²)
Δ = 0.0933
k = 1 / √((1 − N²/n₀²)² + (ΔN/n₀)²)
DYNAMIC MAGNIFIER = k
FREQUENCY = N - CYCLES PER SECOND
DERIVED DATA FROM EXPERIMENTAL VALUES
NATURAL FREQUENCY = n₀ = 9.20
MAXIMUM DYNAMIC MAGNIFIER = kₘ = 10.70
DAMPING FACTOR = Δ = 0.0933
DAMPING CONSTANT = ρ = 0.00507
DAMPING COEFFICIENT = δ = 0.429
U3 U2 U1
L4 L3 L2 L1 L0

Fig. 15.—Vertical Deflectometer Readings.
Frequency—semi-amplitude curve and, frequency—dynamic magnifier curve.

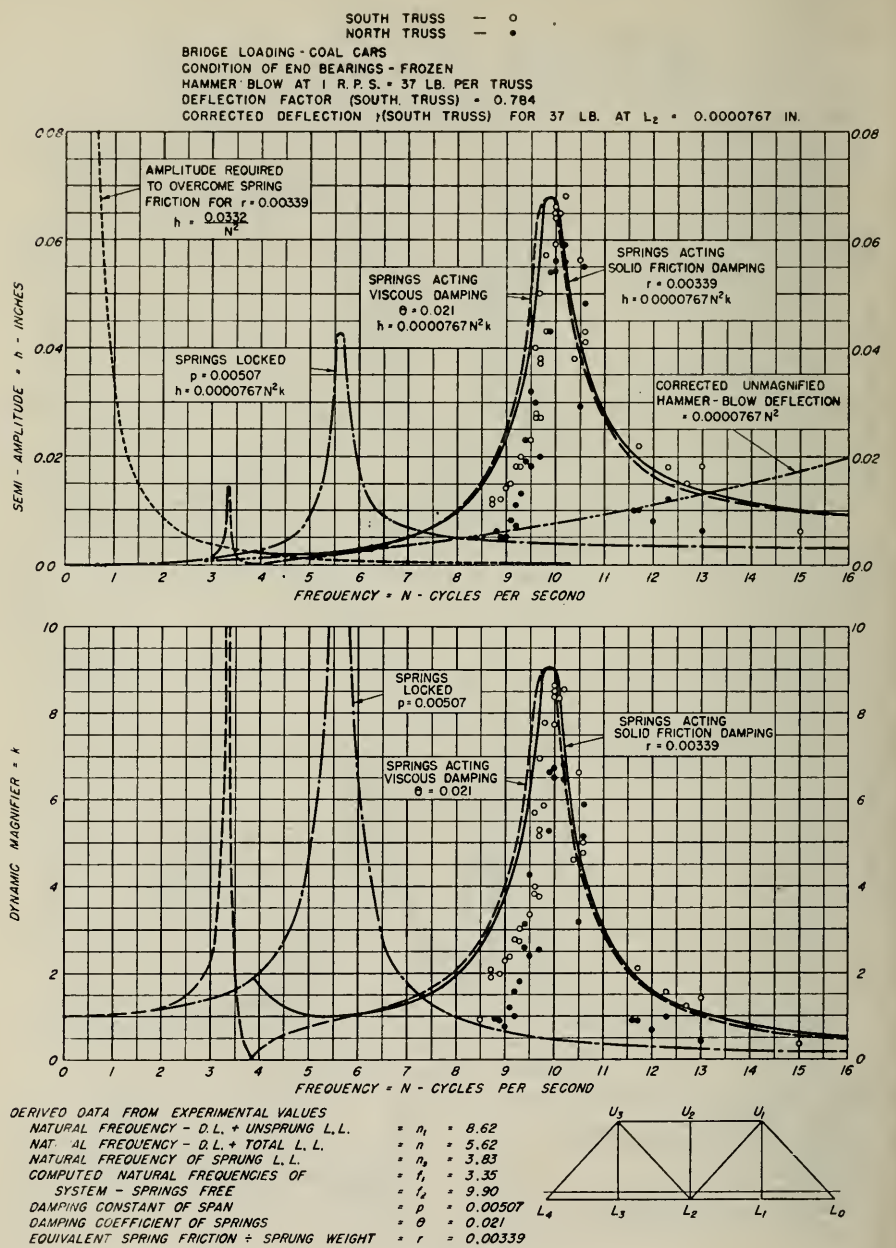

BRIDGE LOADING - NONE
CONDITION OF END BEARINGS - FROZEN
HAMMER BLOW AT 1 R.P.S. = 37 LB. PER TRUSS
STRESS FACTOR = 1.14
CORRECTED STRESS FOR 37 LB. AT L_2 = 0.938 LB PER SQ. IN.
SEMI - AMPLITUDE = h - LB. PER SQ. IN.
Δ = 0
h = 0.938 N² k
Δ = 0.0933
M = 1.26
h = 0.938 N² Mk
Δ = 0.0933
h = 0.938 N² k
CORRECTED UNMAGNIFIED HAMMER - BLOW STRESS = 0.938 N²
FREQUENCY = N - CYCLES PER SECOND
DYNAMIC MAGNIFIER = k
Δ = 0
$k = \frac{1}{1 - \frac{N^2}{n_0^2}}$
Δ = 0.0933
$k = \frac{1}{\sqrt{\left(1 - \frac{N^2}{n_0^2}\right)^2 + \left(\Delta \frac{N}{n_0}\right)^2}}$
Δ = 0.0933
M = 1.26
$Mk = \frac{1.26}{\sqrt{\left(1 - \frac{N^2}{n_0^2}\right)^2 + \left(\Delta \frac{N}{n_0}\right)^2}}$
FREQUENCY = N - CYCLES PER SECOND

DERIVED DATA FROM EXPERIMENTAL VALUES

NATURAL FREQUENCY	= n_0	=	9.20
MEMBER MAXIMUM DYNAMIC MAGNIFIER	= Mk_m	=	13.50
DEFLECTION MAXIMUM DYNAMIC MAGNIFIER	= k_m	=	10.70
MEMBER FACTOR	= M	=	1.26
DEFLECTION DAMPING FACTOR	= Δ	=	0.0933
DEFLECTION DAMPING CONSTANT	= p	=	0.00507
DEFLECTION DAMPING COEFFICIENT	= δ	=	0.429

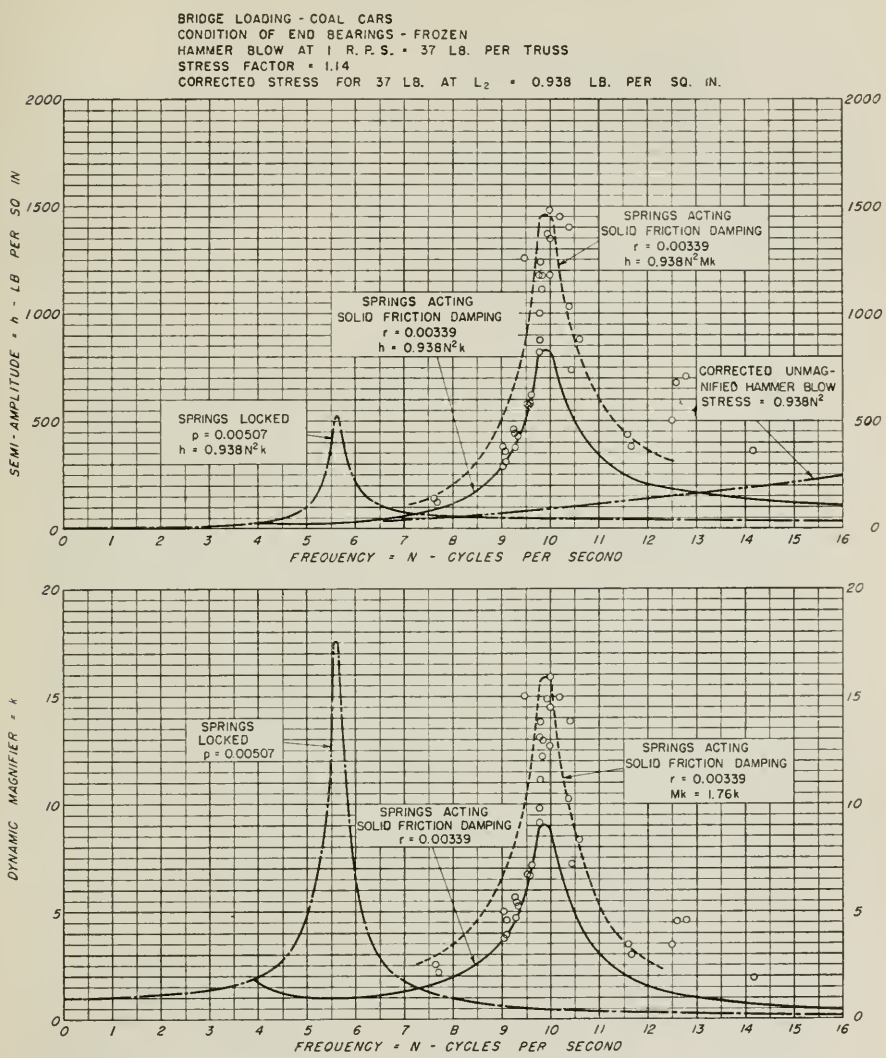
Fig. 16.—Member $L_0 U_1$.

Frequency—semi-amplitude curve and, frequency—dynamic magnifier curve strain gage readings


SOUTH TRUSS — o
NORTH TRUSS — •
BRIDGE LOADING - COAL CARS
CONDITION OF END BEARINGS - FROZEN
HAMMER BLOW AT 1 R.P.S. = 37 LB. PER TRUSS
DEFLECTION FACTOR (SOUTH TRUSS) = 0.784
CORRECTED DEFLECTION (SOUTH TRUSS) FOR 37 LB. AT L2 = 0.0000767 IN.
AMPLITUDE REQUIRED TO OVERCOME SPRING FRICTION FOR r = 0.00339
h = 0.0332/N²
SPRINGS ACTING VISCOUS DAMPING θ = 0.021 h = 0.0000767 N²k
SPRINGS ACTING SOLID FRICTION DAMPING r = 0.00339 h = 0.0000767 N²k
SPRINGS LOCKED p = 0.00507 h = 0.0000767 N²k
CORRECTED UNMAGNIFIED HAMMER-BLOW DEFLECTION = 0.0000767 N²
SEMI-AMPLITUDE = h - INCHES
FREQUENCY = N - CYCLES PER SECOND
SPRINGS LOCKED p = 0.00507
SPRINGS ACTING SOLID FRICTION DAMPING r = 0.00339
SPRINGS ACTING VISCOUS DAMPING θ = 0.021
DYNAMIC MAGNIFIER = k
FREQUENCY = N - CYCLES PER SECOND

DERIVED DATA FROM EXPERIMENTAL VALUES		
NATURAL FREQUENCY - D.L. + UNSPRUNG L.L.	= n_1	= 8.62
NATURAL FREQUENCY - D.L. + TOTAL L.L.	= n	= 5.62
NATURAL FREQUENCY OF SPRUNG L.L.	= n_s	= 3.83
COMPUTED NATURAL FREQUENCIES OF	= f_1	= 3.35
SYSTEM - SPRINGS FREE	= f_2	= 9.90
DAMPING CONSTANT OF SPAN	= p	= 0.00507
DAMPING COEFFICIENT OF SPRINGS	= θ	= 0.021
EQUIVALENT SPRING FRICTION ÷ SPRUNG WEIGHT	= r	= 0.00339
MAXIMUM DYNAMIC MAGNIFIER	= k_m	= 9.05

Fig. 17.—Vertical Deflectometer Readings.
Frequency—semi-amplitude curve and, frequency—dynamic magnifier curve.


BRIDGE LOADING - COAL CARS
CONDITION OF END BEARINGS - FROZEN
HAMMER BLOW AT 1 R. P. S. = 37 LB. PER TRUSS
STRESS FACTOR = 1.14
CORRECTED STRESS FOR 37 LB. AT L_2 = 0.938 LB. PER SQ. IN.
SEMI-AMPLITUDE = h - LB PER SQ IN
SPRINGS ACTING SOLID FRICTION DAMPING r = 0.00339 h = 0.938N²Mk
SPRINGS ACTING SOLID FRICTION DAMPING r = 0.00339 h = 0.938N²k
CORRECTED UNMAGNIFIED HAMMER BLOW STRESS = 0.938N²
SPRINGS LOCKED p = 0.00507 h = 0.938N²k
FREQUENCY = N - CYCLES PER SECOND
DYNAMIC MAGNIFIER = k
SPRINGS LOCKED p = 0.00507
SPRINGS ACTING SOLID FRICTION DAMPING r = 0.00339 Mk = 1.76k
SPRINGS ACTING SOLID FRICTION DAMPING r = 0.00339
FREQUENCY = N - CYCLES PER SECOND

DERIVED DATA FROM EXPERIMENTAL VALUES		
NATURAL FREQUENCY - O. L. + UNSPRUNG L. L.	$= n_1$	= 8.62
NATURAL FREQUENCY - O. L. + TOTAL L. L.	$= n$	= 5.62
NATURAL FREQUENCY OF SPRUNG L. L.	$= n_s$	= 3.83
COMPUTED NATURAL FREQUENCIES OF	$= f_1$	= 3.35
SYSTEM - SPRINGS FREE	$= f_2$	= 9.90
DAMPING CONSTANT OF SPAN	$= p$	= 0.00507
DAMPING COEFFICIENT OF SPRINGS	$= \theta$	= 0.021
EQUIVALENT SPRING FRICTION ÷ SPRUNG WEIGHT	$= r$	= 0.00339
MEMBER DYNAMIC MAGNIFIER	$= Mk_m$	= 15.90
DEFLECTION DYNAMIC MAGNIFIER	$= k_m$	= 9.05
MEMBER FACTOR	$= M$	= 1.76

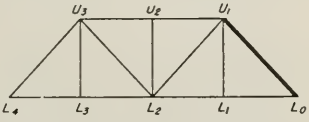


Fig. 18.—Member $L_0 U_1$.
Frequency—semi-amplitude curve and, frequency—dynamic magnifier curve strain gage readings.

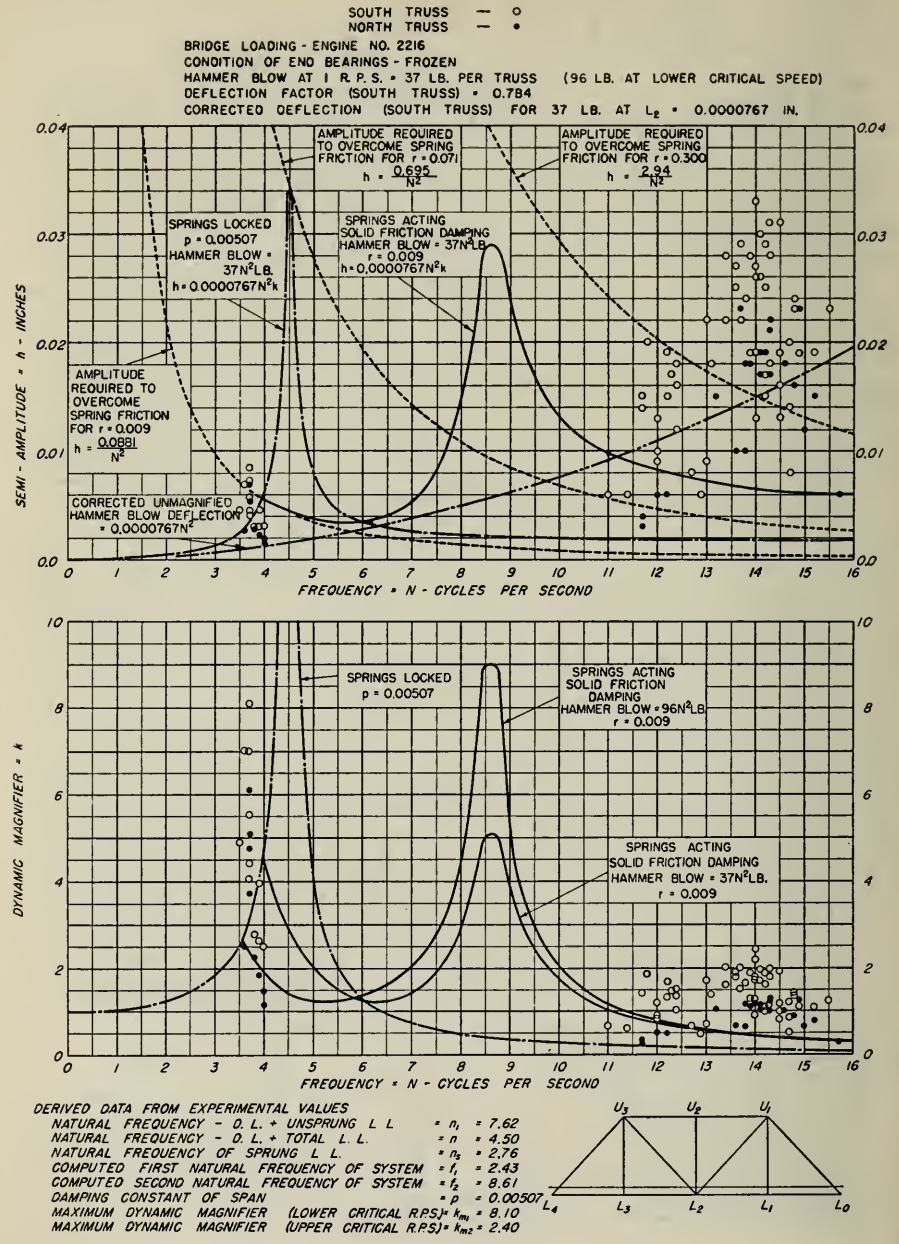
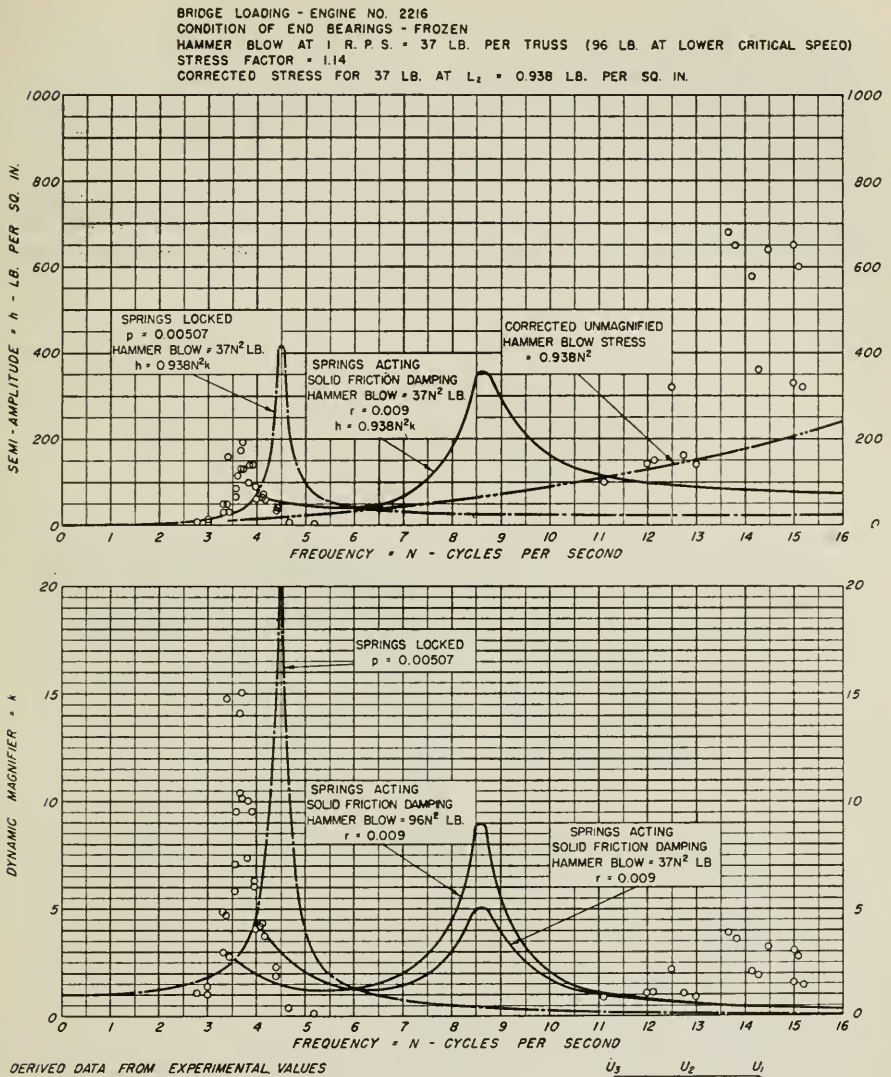

SOUTH TRUSS — o
NORTH TRUSS — •
BRIDGE LOADING - ENGINE NO. 2216
CONDITION OF END BEARINGS - FROZEN
HAMMER BLOW AT 1 R. P. S. = 37 LB. PER TRUSS (96 LB. AT LOWER CRITICAL SPEED)
DEFLECTION FACTOR (SOUTH TRUSS) = 0.784
CORRECTED DEFLECTION (SOUTH TRUSS) FOR 37 LB. AT L_2 = 0.0000767 IN.
AMPLITUDE REQUIRED TO OVERCOME SPRING FRICTION FOR r = 0.071 h = 0.695/N²
AMPLITUDE REQUIRED TO OVERCOME SPRING FRICTION FOR r = 0.300 h = 2.94/N²
SPRINGS LOCKED p = 0.00507 HAMMER BLOW = 37N²LB. h = 0.0000767N²k
SPRINGS ACTING SOLID FRICTION DAMPING HAMMER BLOW = 37N²LB. r = 0.009 h = 0.0000767N²k
AMPLITUDE REQUIRED TO OVERCOME SPRING FRICTION FOR r = 0.009 h = 0.0881/N²
CORRECTED UNMAGNIFIED HAMMER BLOW DEFLECTION = 0.0000767N²
SEMI - AMPLITUDE = h - INCHES
FREQUENCY = N - CYCLES PER SECOND
SPRINGS LOCKED p = 0.00507
SPRINGS ACTING SOLID FRICTION DAMPING HAMMER BLOW = 96N²LB. r = 0.009
SPRINGS ACTING SOLID FRICTION DAMPING HAMMER BLOW = 37N²LB. r = 0.009
DYNAMIC MAGNIFIER = k
FREQUENCY = N - CYCLES PER SECOND
DERIVED DATA FROM EXPERIMENTAL VALUES
NATURAL FREQUENCY - O. L. + UNSPRUNG L L = n_1 = 7.62
NATURAL FREQUENCY - O. L. + TOTAL L. L. = n = 4.50
NATURAL FREQUENCY OF SPRUNG L L. = n_2 = 2.76
COMPUTED FIRST NATURAL FREQUENCY OF SYSTEM = f_1 = 2.43
COMPUTED SECOND NATURAL FREQUENCY OF SYSTEM = f_2 = 8.61
DAMPING CONSTANT OF SPAN = p = 0.00507
MAXIMUM DYNAMIC MAGNIFIER (LOWER CRITICAL R.P.S.) = k_{m_1} = 8.10
MAXIMUM DYNAMIC MAGNIFIER (UPPER CRITICAL R.P.S.) = k_{m_2} = 2.40
U_3 U_2 U_1
L_4 L_3 L_2 L_1 L_0

Fig. 19.—Vertical Deflectometer Readings.

Frequency—semi-amplitude curve and, frequency—dynamic magnifier curve.


BRIDGE LOADING - ENGINE NO. 2216
CONDITION OF END BEARINGS - FROZEN
HAMMER BLOW AT I R. P. S. = 37 LB. PER TRUSS (96 LB. AT LOWER CRITICAL SPEED)
STRESS FACTOR = 1.14
CORRECTED STRESS FOR 37 LB. AT L_2 = 0.938 LB. PER SQ. IN.
SEMI-AMPLITUDE = h - LB. PER SQ. IN.
SPRINGS LOCKED
p = 0.00507
HAMMER BLOW = $37N^2$ LB.
$h = 0.938N^2k$
SPRINGS ACTING
SOLID FRICTION DAMPING
HAMMER BLOW = $37N^2$ LB.
r = 0.009
$h = 0.938N^2k$
CORRECTED UNMAGNIFIED
HAMMER BLOW STRESS
$= 0.938N^2$
FREQUENCY = N - CYCLES PER SECOND
DYNAMIC MAGNIFIER = k
SPRINGS LOCKED
p = 0.00507
SPRINGS ACTING
SOLID FRICTION DAMPING
HAMMER BLOW = $96N^2$ LB.
r = 0.009
SPRINGS ACTING
SOLID FRICTION DAMPING
HAMMER BLOW = $37N^2$ LB
r = 0.009
FREQUENCY = N - CYCLES PER SECOND

DERIVED DATA FROM EXPERIMENTAL VALUES

NATURAL FREQUENCY - O. L. + UNSPRUNG L. L.		$= n_1 = 7.62$
NATURAL FREQUENCY - O. L. + TOTAL L. L.		$= n = 4.50$
NATURAL FREQUENCY OF SPRUNG L L.		$= n_s = 2.76$
COMPUTED FIRST NATURAL FREQUENCY OF SYSTEM		$= f_1 = 2.43$
COMPUTED SECOND NATURAL FREQUENCY OF SYSTEM		$= f_2 = 8.61$
DAMPING CONSTANT OF SPAN		$= p = 0.00507$
	LOWER CRITICAL R.P.S.	UPPER CRITICAL R.P.S.
MEMBER DYNAMIC MAGNIFIER	$M_1k_{m1} = 15.10$	$M_2k_{m2} = 3.90$
DEFLECTION DYNAMIC MAGNIFIER	$k_{m1} = 8.10$	$k_{m2} = 2.40$
MEMBER FACTOR	$M_1 = 1.86$	$M_2 = 1.63$

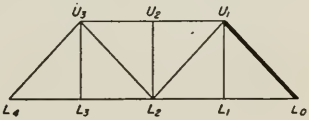


Fig. 20.—Member $L_0 U_1$.

Frequency—semi-amplitude curve and, frequency—dynamic magnifier curve strain gage readings.

$$k = \frac{h}{D_h N^2} \quad \ldots\ldots (6)$$

This procedure was followed for all runs, k being computed for each frequency used during the run. Typical measured semi-amplitudes are represented by the plotted points in the upper diagrams of Figs. 15 to 20, incl. The corresponding dynamic magnifiers are plotted in the lower diagrams of the same figures.

For the lower range of frequencies with locomotives 2216 and 2244 on the span, a hammer blow of 96 lb. per rotor was used. In plotting these points (Figs. 19 and 20) the semi-amplitudes were reduced to equivalent ones for a hammer blow of 37 lb. per rotor in order to keep the scale the same throughout.

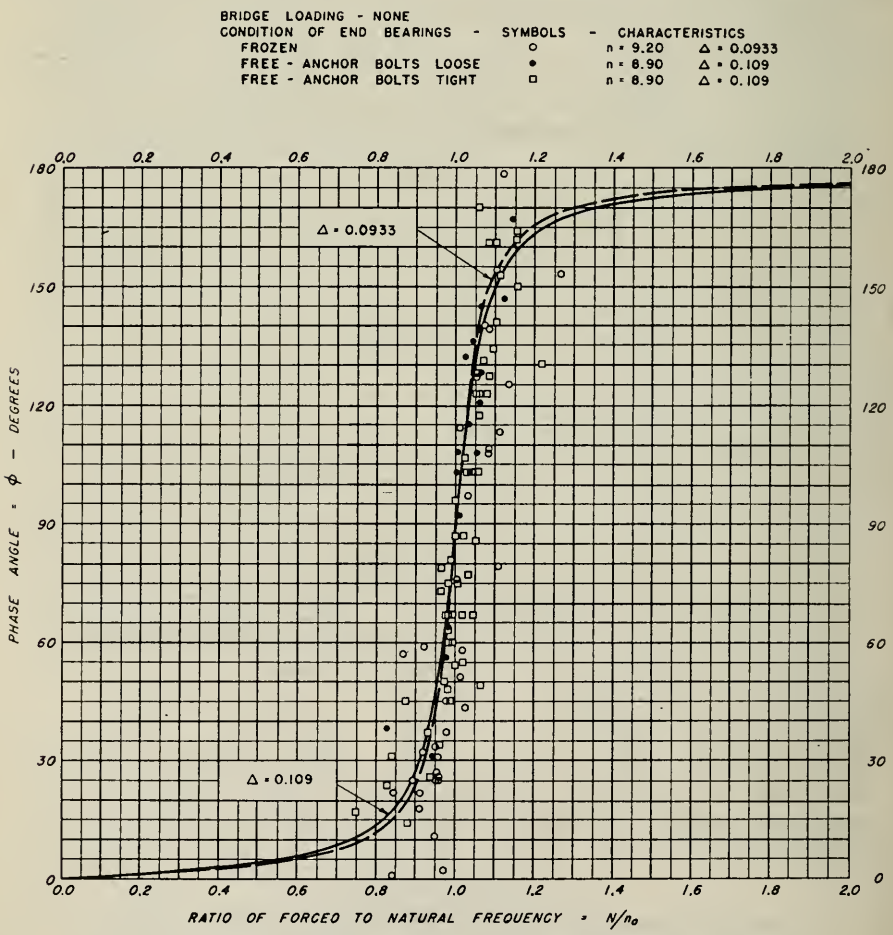

BRIDGE LOADING - NONE
CONDITION OF END BEARINGS - SYMBOLS - CHARACTERISTICS
FROZEN ○ n = 9.20 Δ = 0.0933
FREE - ANCHOR BOLTS LOOSE ● n = 8.90 Δ = 0.109
FREE - ANCHOR BOLTS TIGHT □ n = 8.90 Δ = 0.109
Δ = 0.0933
Δ = 0.109
PHASE ANGLE = φ - DEGREES
RATIO OF FORCED TO NATURAL FREQUENCY = N/n₀
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0
0 30 60 90 120 150 180

Fig. 21.—Frequency—Phase Angle Curve Strain Gage Readings.

Determination of Natural Frequencies

The undamped natural frequency n_o of the span under dead load for any particular end bearing condition was found by an examination of the plotted dynamic magnifiers as shown in typical Figs. 15 and 16. For a given set of end bearing conditions, the graphs of k as plotted from the test data were assembled, and empirical dynamic magnifier curves roughly sketched. For each graph, the value of N at which $k = k_m$, the maximum, was determined and the average of these values was taken as N_s, the synchronous frequency. None of these frequencies for which $k = k_m$ differed from the average by more than 0.1 rps. For an undamped system, k increases without limit in the neighborhood of n_o, and $n_o = N_s$. In the damped system being considered, n_o was taken equal to N_s as determined above, the error in this procedure being negligible as will be seen from the following paragraphs.

The theoretical value of the dynamic magnifier for the bridge under dead load will be shown in the mathematical preliminary to be:

$$k = \frac{1}{\sqrt{\left(1-\frac{N^2}{n_o^2}\right)^2 + \left(\Delta \frac{N}{n_o}\right)^2}} \qquad (7)$$

where n_o and N have been defined, and Δ is the "damping factor" of the span. To determine the ratio of $\frac{N}{n_o}$ at which $k = k_m$, the maximum, differentiate k with respect to $\frac{N}{n_o}$ and equate the derivative to zero. Thus:

$$\frac{dk}{d\left(\frac{N}{n_o}\right)} = \frac{\frac{N}{n_o}\left(2\frac{N^2}{n_o^2} - 2 + \Delta^2\right)}{\left[\left(1-\frac{N^2}{n_o^2}\right)^2 + \left(\Delta\frac{N}{n_o}\right)^2\right]^{\frac{3}{2}}} = 0 \qquad (8)$$

The solution $\frac{N}{n_o} = 0$ gives a minimum value of k. Setting the other factor

$2\frac{N^2}{n_o^2} - 2 + \Delta^2 = 0$, solving for Δ in terms of $\frac{N}{n_o}$, substituting in the equation for k, and solving for $\frac{N}{n_o}$, we obtain

$$\frac{N_s}{n_o} = \left(1 - \frac{1}{k_m^2}\right)^{\frac{1}{4}} \qquad (9)$$

This equation shows that for all finite values of k_m, $\frac{N_s}{n_o} < 1$. Furthermore, if $\underline{k}_m$ is a lower bound of k_m, the equality in equation (9) is replaced by $\leq$. Therefore,

$$\left(1-\frac{1}{\underline{k}_m^2}\right)^{\frac{1}{4}} \leq \frac{N_s}{n_o} < 1 \qquad (10)$$

and limits of error in assuming $n_o = N_s$ have been established.

In analyzing the dead load tests, it was found that the maximum dynamic magnifiers as determined from deflection data were not less than 9.0. The error in assuming $n_o = N_s$ in these cases was therefore not greater than 0.3 percent, which was within the accuracy with which N_s could be determined.

Natural frequencies for the reduction of live load data were obtained by theoretical computation. It has been shown[9] that the first natural frequency of a girder is very closely represented by the formula:

$$n = \sqrt{\frac{12.4}{d}} \quad \ldots\ldots (11)$$

where n is the frequency in rps. and d is the center deflection in inches. Since the above formula is based on an anlysis of a uniform beam, it was to be expected that only mediocre results would be obtained in applying it to a truss. The computation of the natural frequency of a truss by rational methods is such a complicated task as to be impractical of application.[7] It was therefore decided to use a formula similar to (11), but with an empirical factor replacing the factor 12.4. It was assumed that this empirical factor obtained for one loading and end bearing condition could be used with sufficient accuracy for all other loadings with the same end bearing condition. Since all live load tests were conducted with end bearings frozen, only the empirical factor for that condition was needed. The natural frequency n_o for dead load having been found by the method already described, the empirical factor C was computed by the equation:

$$n = \sqrt{\frac{C}{d}} \quad \ldots\ldots (12)$$

For dead load and end bearings frozen, $n_o = 9.20$ and $d = 0.1506$ in. (Table 1.) Then $C = 12.75$, and the frequency formula became

$$n = \sqrt{\frac{12.75}{d}} \quad \ldots\ldots (13)$$

The theoretical value of d was used in obtaining C, which therefore contains the correction for deflection factor and all other modifying effects.

The natural frequencies of the bridge under live load with springs acting were then computed by the formula[9]

$$f^4 - f^2 n^2_1 \left(1 + \frac{n^2_s}{n^2}\right) + n^2_1 \, n^2_s = 0 \quad \ldots\ldots (14)$$

Where n = natural frequency of span when loaded with entire live load and springs locked.

n_1 = natural frequency of span when loaded with unsprung live load.

n_s = natural frequency of sprung live load on its own springs.

In using formula (14), n and n_1 were computed by equation (13). The frequency of the sprung weight of the locomotives was taken from Table 14, and the frequency of the sprung weights of tenders and coal cars were computed by the formula[9]

$$n_s = \sqrt{\frac{9.8}{d}} \quad \ldots\ldots (15)$$

[9] pp. 22–23.
[9] p. 39; p. 22.

The value of n_s used in equation (14) was the average for all loads on the span, all springs being considered as free.

It should be noted that since equation (14) is quadratic in f^2, two solutions for f^2 and therefore two positive values of f were obtained. These values, f_1 and f_2, are tabulated in Figs. 17–20, incl.

In view of the poor agreement between test results and the values of f_2 computed above for locomotive live loads, several other computing procedures were tried. Analyses were made for the case of locomotive springs free and tender springs locked, locomotive springs locked and tender springs free, and the three degree of freedom system wherein both locomotive and tender springs were free and their different natural frequencies considered.

This latter case gives rise to the complicated equation:

$$\frac{f^6}{n^2_1} - f^4\left[1 + \frac{n^2_2}{n^2_{12}} + \frac{n^2_3}{n^2_{13}}\right] + f^2\left[n^2_2 + n^2_3 + \frac{n^2_2\ n^2_3}{n^2_{123}}\right] - n^2_2\ n^2_3 = 0 \quad \ldots\ldots\ldots\ldots (16)$$

Where n_1 = natural frequency of bridge under unsprung live load.
n_2 = natural frequency of locomotive sprung weight.
n_3 = natural frequency of tender sprung weight.
n_{12} = natural frequency of bridge under unsprung live load plus sprung weight of locomotive (locomotive springs locked).
n_{13} = natural frequency of bridge under unsprung live load plus sprung weight of tender (tender springs locked).
n_{123} = natural frequency of span under total live load (locomotive and tender springs locked).

Formula (16) naturally gave three positive values of f, of which f_1 and f_2 were very close to the value of f_1 as computed from equation (14), and f_3 was close to the f_2 obtained from equation (14). Since equation (16) has been simplified by the omission of all damping terms, its use in the analysis was considered impractical and its derivation is therefore omitted.

Determination of Damping Factors

The damping factors, Δ, for oscillation of the span under dead load with various end bearing conditions were computed from deflection data by the formula

$$\Delta = \frac{\sqrt{\left(\frac{1}{k} + 1 - \frac{N^2}{n^2_o}\right)\left(\frac{1}{k} - 1 + \frac{N^2}{n^2_o}\right)}}{\frac{N}{n_o}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

which results from solving equation (7) for Δ.

After establishing n_o for any set of conditions, five or six of the experimentally determined values of k lying on the interval $n_o - 1 < N < n_o + 1$ were chosen at random and the Δ corresponding to each computed. The average of these was taken as the experimental Δ for a particular set of conditions. In arriving at this average, individual values deviating by more than 10 percent from the mean were disregarded and replaced. Since it was desired to correlate stress and deflection measurements, and no stresses were measured on the north truss, only south truss deflections were considered in evaluating Δ.

Typical theoretical curves of dynamic magnifier versus hammer blow frequency for the experimental values of Δ and for $\Delta = 0$ are shown for the span under dead load tests in the lower diagrams of Figs. 15 and 16. The corresponding curves of

deflection or stress semi-amplitude versus hammer blow frequency are shown in the upper diagrams of the figures. These curves were simply computed by the formula

$$h = \frac{Dh\ N^2}{\sqrt{\left(1-\frac{N^2}{n_o^2}\right)^2+\left(\Delta\frac{N}{n_o}\right)^2}} \quad \ldots\ldots(18)$$

which is derived by combining equations (6) and (7).

Having obtained Δ for a given set of end bearing conditions and dead load, the "damping constant" for the span with that end bearing condition is given by the equation

$$p = \frac{\Delta}{2\ n_o} \quad \ldots\ldots(19)$$

With the "damping constant" p[0] found by equation (19), a new value of the damping factor Δ can be computed for any other load condition giving a natural frequency n. This new value of Δ is given by the equation

$$\Delta = 2pn \quad \ldots\ldots(20)$$

Typical theoretical curves of dynamic magnifier and deflection or stress semi-amplitude versus hammer blow frequency under live load are shown in Figs. 17 to 20, incl. Curves for the case of locked springs were computed from the formulas

$$k = \frac{1}{\sqrt{\left(1-\frac{N^2}{n_z^2}\right)^2+\left(\Delta\frac{N}{n}\right)^2}} \quad \ldots\ldots(21)$$

and

$$h = \frac{D_h\ N^2}{\sqrt{\left(1-\frac{N^2}{n^2}\right)^2+\left(\Delta\frac{N}{n}\right)^2}} \quad \ldots\ldots(22)$$

These formulas are the same as those used for the dead load condition except than n_o has been replaced by n the natural frequency of the span under total live load with springs locked, and that the Δ is a new one computed from equation (20).

Typical theoretical curves of dynamic magnifier and semi-amplitude for live load with springs acting and assuming various spring damping conditions are also shown in Figs. 17 to 20, incl. These have been computed by the formula

$$h = D_h N^2 \sqrt{\frac{\left(N^2 - n_s^2\right)^2+\left(2N\theta\right)^2}{\phi^2+\psi^2}} = D_h\ N^2\ k \quad \ldots\ldots(23)$$

where

$$\phi = \frac{N^4}{n_1^2} - N^2\left[1+4p\theta+\frac{n_s^2}{n^2}\right]+n_s^2 \quad \ldots\ldots(24)$$

and

$$\psi = 2N\left[\theta\ \frac{n^2-N^2}{n^2} + p\left(n_s^2-N^2\right)\right] \quad \ldots\ldots(25)$$

[0] p. 33.

Here N, n, n_1, and n_s are as previously defined. In addition

p = damping constant of span as found from dead load tests (equation 19).
Θ = damping coefficient of locomotive springs.

It may be noted in passing that the approximate formula for the natural frequencies, equation (14), is derived by equating ϕ (equation 24) to zero, and assuming that the damping terms are small enough to be negligible.

Fig. 17 shows curves computed from equation (23) on the assumption that the damping was viscous, the value of Θ being determined by a process similar to that described for the dead load condition, and assumed constant for the given live load.

Other curves for the case of live load with springs acting and based upon the assumption that the spring friction was constant, that is, "solid" or "Coulomb" friction, are shown on Figs. 17 to 20, incl. In this case, equation (23) was used by substituting for the constant spring friction (independent of velocity of displacement) an equivalent "viscous" spring friction which would have the same energy dissipation per cycle. Thus if the constant spring friction be assumed to be F, the equivalent "viscous" spring friction would be a harmonic force of frequency N and peak value $F' = \frac{4F}{\pi}$. Then the equivalent Θ will be the positive root of the equation

$$\left[\frac{2\pi^3 D_h N^5 W_s}{F g}\right]^2 \Theta^2 = \phi^2 + \psi^2 \quad \text{----------} \quad (26)$$

where W_s = the equivalent concentrated center load which would give the same deflection as the distributed sprung weight of live load

g = acceleration of gravity.

ϕ and ψ are given by equation (24) and (25).

Having computed Θ for each N from equation (26), the semi-amplitude of oscillation of the bridge center line was determined by the equation

$$h = \frac{F g \sqrt{\left(N^2 - n_s^2\right)^2 + \left(2 N \Theta\right)^2}}{W_s \, 2\pi^3 N^3 \Theta}$$

$$= \frac{r \sqrt{\left(N^2 - n_s^2\right)^2 + \left(2 N \Theta\right)^2}}{0.204 \, N^3 \, \Theta}$$

$$= D_h N^2 k \quad \text{----------} \quad (27)$$

where the constant spring friction F has been expressed in dimensionless form r by the equation

$$r = \frac{F'}{W_s} = \frac{4F}{\pi W_s} \quad \text{----------} \quad (28)$$

These formulas (23) to (28) incl. and their use have been discussed in Reference (9), pages 37–40.

By equation (26) it can be seen that, surprisingly enough, Θ is a function of D_h as well as r. Since Θ must be real and positive, the maximum possible value of r is limited by the value of D_h, and since the oscillator gave much smaller hammer blows than a locomotive, the values of r given on Figs. 17 to 20, incl. are very small by comparison with the 0.10 to 0.15 found by Mr. Hunley.[9]

Phase Angle Measurements

Because of the very doubtful accuracy of the method of measuring phase angles, these data were only reduced for the dead load tests. In this case the system was practically of one degree of freedom. Then if the hammer blow is supposed to vary according to the formula

$$P = F \sin 2\pi Nt \quad \text{----------} \quad (29)$$

the theoretical steady state deflection will be given by the equation

$$H = h \sin (2\pi Nt - \phi)$$

$$= \frac{d \sin (2\pi N - \phi)}{\sqrt{\left(1 - \frac{N^2}{n_o^2}\right)^2 + \left(\Delta \frac{N}{n_o}\right)^2}} \quad \text{----------} \quad (30)$$

d being as previously defined under the Computation of Dynamic Magnifiers, and the positive root always being chosen. It will be shown later that the phase angle is given by the equation

$$\phi = \arctan \frac{\Delta \frac{N}{n_o}}{1 - \frac{N^2}{n_o^2}} \quad \text{----------} \quad (31)$$

Where $0 \leqq \phi \leqq 180$ deg. A direct study of the differential equation of motion for the case of no damping[5] leads to the equation

$$H = \frac{d}{1 - \frac{N^2}{n_o^2}} \sin 2\pi Nt \quad \text{----------} \quad (32)$$

In order to make the general formula (30) fit this case, it is usual to adopt the convention that when $\Delta = 0$, $\phi = 0$ for $\frac{N}{n_o} < 1$ and $\phi = 180$ deg. for $\frac{N}{n_o} > 1$. The change in sign of H in the special case as $\frac{N}{n_o}$ passes through 1 is thus accounted for. As with equation (5), equations (30) and (32) will later be modified when the displacements represent stresses, but the modification leaves ϕ unchanged.

[5] pp. 14–16.

The process of obtaining ϕ from the test records has already been explained. These values are shown plotted in Fig. 21, the accompanying curves being the theoretical ones obtained by substituting the experimental values of Δ in equation (31).

8. Impact and Damping as Found from the Test Data

Mathematical Preliminary

A truss bridge under the passage of a locomotive and cars is a dynamical system of such complexity that a complete analysis of its motion, so far as can be ascertained, has never been presented. Even when only free oscillations under dead load are considered[7] the algebraic complications are enormous. In the ensuing discussion, the example of Inglis[2] will be followed and the bridge idealized as a uniform beam in which all deformation results from bending. The situation is extended by analogy to the span under consideration.

Consider the beam of Fig. 12. P_v and c_v represent all of the concentrated forces and their points of application. The sense of coordinates is as shown, and the deflections are measured from the static deflection position, which is permissible if the principle of superposition be assumed to hold. The ends are regarded as hinged.

The notation used is as follows:

E = modulus of elasticity
I = moment of inertia
m = mass per unit length
L = length of span
y = deflection at point x
t = time
$a^2 = \frac{EI}{m}$

The oscillations of this system when there is no damping have been studied and the solution is well known.[6] The following solution for the damped case follows a similar pattern, the notation being preserved except for obvious changes.

Assume that the deflection curve can be represented by the trigonometric series

$$y = \sum_{i=1}^{\infty} q_i \sin \frac{i\pi x}{L} \qquad (33)$$

where ρ_i is a generalized coordinate of the system. Each ρ_i will, in general, be a function of time. Newton's dot notation will be used for ordinary time derivatives.

The generalized force Q_i resulting from the action of the applied forces when an increment is given to ρ_i is*

$$Q_i = \sum P_v \sin \frac{i\pi c_v}{L} \qquad (34)$$

[6] pp. 348–352.
* Ibid.. pp. 188–189.

where the summation is over all forces acting, and should be replaced by an integration in the case of a distributed force. That is, if a distributed force $p_o(x)$ per unit length is acting.

$$Q_i = \int_0^L p(x) \sin \frac{i\pi x}{L} dx \quad \text{----------} \quad (35)$$

The kinetic energy of the system is*

$$T = \frac{mL}{4} \sum_{i=1}^{\infty} \dot{q}_i^2 \quad \text{----------} \quad (36)$$

and the potential energy is**

$$V = \frac{ma^2\pi^4}{4L^3} \sum_{i=1}^{\infty} i^4 q_i^2 \quad \text{----------} \quad (37)$$

Now suppose the applied forces are a single concentrated alternating force $F \sin \omega t$ acting at $x = c$, and a distributed "viscous" damping force proportional to the velocity of the element on which it acts. The generalized forces will then be composed of two parts corresponding to the exciting force and the damping. Use the notation U_i for the former part. Then by equation (34)

$$U_i = F \sin \frac{i\pi c}{L} \sin \omega t \quad \text{----------} \quad (38)$$

Let the damping force per unit length be ∇^2

$$p(x) = -4\pi m \delta \frac{\partial y}{\partial t} \quad \text{----------} \quad (39)$$

From equation (33)

$$\frac{\partial y}{\partial t} = \sum_{i=1}^{\infty} \dot{q}_i \sin \frac{i\pi x}{L} \quad \text{----------} \quad (40)$$

Hence

$$p(x) = -4\pi m \delta \left(\sum_{i=1}^{\infty} \dot{q}_i \sin \frac{i\pi x}{L} \right) \text{----------} (41)$$

And by equation (35) the generalized force corresponding to the damping is

$$W_i = -4\pi m \delta \int_0^L \sin \frac{i\pi x}{L} \left(\sum_{y=1}^{\infty} \dot{q}_y \sin \frac{y\pi x}{L} \right) dx \text{ - - -} (42)$$

* Ibid., pp. 188–189.
** Ibid., p. 348.
* Ch. VI, and Reference 9 p. 29.

where the subscript within the parentheses has been changed to avoid confusion.

Evaluating equation (42)

$$W_i = -2\pi m \delta L \dot{q}_i \text{ - - - - - - - - - - - - - - - - - (43)}$$

Lagrange's equation of motion [4]

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}_i}\right) - \frac{\partial T}{\partial q_i} + \frac{\partial V}{\partial q_i} = Q_i \text{ - - - - - - - - - - - - - - - (44)}$$

are then, for the system considered

$$\frac{mL}{2}\ddot{q}_i + \frac{ma^2\pi^4 i^4}{2L^3} q_i = F \sin\frac{i\pi c}{L} \sin\omega t - 2\pi m \delta L \dot{q}_i \text{ - - - - - (45)}$$

which, upon dividing by $\frac{mL}{2}$, transposing, and noting that the undamped natural frequencies of free vibration of a hinged beam are [5]

$$\omega_i = \frac{a\pi^2 i^2}{L^2} \text{ - - - - - - - (46)}$$

becomes

$$\ddot{q}_i + 4\pi\delta\dot{q}_i + \omega_i^2 q_i = \frac{2F}{mL} \sin\frac{i\pi c}{L} \sin\omega t \text{ - - - - - - - (47)}$$

This is a system of second order linear differential equations, each containing only one unknown. Therefore the solution of each equation is independent of the others. The solution is [1]

$$q_i = e^{-2\pi\delta t}\left(C_1 \cos\omega_i' t + C_2 \sin\omega_i' t\right) + \\ + \frac{2F \sin\frac{i\pi c}{L} \sin(\omega t - \phi_i)}{mL\sqrt{(\omega_i^2 - \omega^2)^2 + 16\pi^2\delta^2\omega^2}} \text{ - - - - - - - (48)}$$

where

$$\omega_i' = \sqrt{\omega_i^2 - 4\pi^2\delta^2} \quad \text{(the damped natural frequency)}$$

$$\phi_i = \arctan\frac{4\pi\delta\omega}{\omega_i^2 - \omega^2}$$

C_1 and C_2 are undetermined constants.

The first term of the right hand side of equation (48) is the "transient," and constants C_1 and C_2 depend on the initial values of y, $\frac{\delta y}{\delta t}$ and $\frac{\delta^2 y}{\delta t^2}$. Since δ is supposed to be positive, this term decreases with increasing time and will eventually be negligible. It will not be further considered in the analysis of the motion. The second term of equation (48) is called the "steady state," and will persist as long as the exciting force acts.

[1] pp. 61–65, Reference 5, pp. 38–40, or any elementary text on differential equations.
[4] Ch. X–XI, and Reference 5, pp. 182–192.
[5] p. 339.

The important part of equation (48) for the present study is then

$$q_i = \frac{2F \sin\frac{i\pi c}{L} \sin(\omega t - \phi_i)}{mL\sqrt{(\omega_i^2-\omega^2)^2 + 16\pi^2\delta^2\omega^2}} \qquad (49)$$

which can also be written in the form

$$q_i = \frac{2F \sin\frac{i\pi c}{L} \sin(\omega t - \phi_i)}{mL\,\omega_i^2\sqrt{\left(1-\frac{\omega^2}{\omega_i^2}\right)^2 + \left(\frac{4\pi\delta\omega}{\omega_i^2}\right)^2}} \qquad (50)$$

To convert this to the notation used in railroad bridge impact studies [9], recall that by equation (46)

$$\omega_i^2 = \frac{a^2\pi^4 i^4}{L^4} = \frac{EI\pi^4 i^4}{mL^4} = i^4\omega_1^2 \qquad (51)$$

and make the substitutions

$$2\pi N = \omega$$
$$2\pi n = \omega_1$$
$$\frac{2\delta}{n} = \Delta$$

Then

$$q_i = \frac{2FL^3 \sin\frac{i\pi c}{L} \sin(2\pi Nt - \phi_i)}{EI\pi^4 i^4\sqrt{\left(1-\frac{N^2}{i^4n^2}\right)^2 + \left(\frac{\Delta N}{i^4 n}\right)^2}} \qquad (52)$$

Substituting equation (52) in equation (33) the series expansion for the elastic curve is found to be

$$y = \frac{2FL^3}{EI\pi^4}\sum_{i=1}^{\infty} \frac{\sin\frac{i\pi c}{L} \sin\frac{i\pi x}{L} \sin(2\pi Nt - \phi_i)}{i^4\sqrt{\left(1-\frac{N^2}{i^4n^2}\right)^2 + \left(\frac{\Delta N}{i^4 n}\right)^2}} \qquad (53)$$

where

$$\phi_i = \arctan\frac{\frac{\Delta N}{n}}{i^4 - \frac{N^2}{n^2}}$$

If $\Delta = 0$, equation (53) reduces to the solution of the undamped system treated by Timoshenko [5].

A study of equation (53) leads to the following conclusions :

(a) For any fixed value of $\frac{N}{n}$ the series converges rapidly because of the factor i^4 in the denominator of each term and the boundedness of the other factors.

(b) Whenever $N = i^2 n$ the "i"th term becomes large, being limited only by the damping.

(c) When $N \leq i^2 n$, $0 \leq \phi_i \leq 90°$. When $N \geq i^2 n$, $90° \leq \phi_i < 180°$

[5] p. 350.

(d) The forced oscillations of the various harmonics of the elastic curve occur at the same frequency as the exciting force, but are, in general, neither in phase with it nor with each other.

(e) For practical values of $\frac{N}{n}$, say $\frac{N}{n} < 2$, the convergence of the series is so rapid that the first term gives a good approximation to the actual deflection curve. This is particularly true if the disturbing force acts at the center of the span, in which case $c = \frac{L}{2}$ and all terms of even index vanish. Inglis[2] has drawn the conclusion that the approximation is adequate if $\frac{1}{3} L < c < \frac{2}{3} L$.

(f) For similar practical values of $\frac{N}{n}$ and $i \geq 2$, ϕ_i is small. That is, the oscillations of index higher than one are nearly in phase with the exciting force.

Regarding the deflection as adequately represented by the first term of equation (53) and letting $\phi_1 = \phi$,

$$y = \frac{\frac{2FL^3}{EI\pi^4} \sin\frac{\pi c}{L} \sin\frac{\pi x}{L} \sin(2\pi Nt - \phi)}{\sqrt{\left(1-\frac{N^2}{n^2}\right)^2 + \left(\Delta\frac{N}{n}\right)^2}} \qquad (54)$$

$$\text{where } \phi = \arctan \frac{\Delta\frac{N}{n}}{1-\frac{N^2}{n^2}}$$

But the deflection at $x = \frac{L}{2}$ which would result from the static application of a force F at $x = \frac{L}{2}$ is

$$d = \frac{FL^3}{48EI} \qquad (55)$$

while the constant factor of equation (54)

$$\frac{2FL^3}{EI\pi^4} = \frac{FL^3}{48.7EI} = d \quad \text{(approximately)} \qquad (56)$$

Equation (54) can therefore be written (approximately)

$$y = \frac{d \sin\frac{\pi c}{L} \sin\frac{\pi x}{L} \sin(2\pi Nt - \phi)}{\sqrt{\left(1-\frac{N^2}{n^2}\right)^2 + \left(\Delta\frac{N}{n}\right)^2}} \qquad (57)$$

Still assuming that the deflection curve is adequately represented by a half sine wave, and applying Maxwell's theorem of reciprocal deflections, it is seen that the deflection at $X = \frac{L}{2}$ produced by a static force F acting at $X = c$ is $d \sin\frac{\pi c}{L}$.

[2] Ch. I.

Then, if the dynamic magnifier k is defined as the ratio of the amplitude of oscillation at the center of the span to the deflection which would be produced there if the forces acted statically, it is found that

$$k = \frac{1}{\sqrt{\left(1 - \frac{N^2}{n^2}\right)^2 + \left(\Delta \frac{N}{n}\right)^2}} \quad \ldots\ldots (58)$$

which is the same as that obtained by Inglis for the case under consideration.[9]

Referring to the transient term of equation (48) it is evident that if ω_1' should vanish or be imaginary, the corresponding motion would not be an oscillation. The minimum value of δ for which this would occur is known as the "critical damping," δ_c. Considering only the index $i = 1$, $\delta_c = \frac{\omega_1}{2\pi} = n$

and

$$\Delta = 2 \frac{\delta}{\delta_c} \quad \ldots\ldots (59)$$

Continuing to refer to the transient term of equation (48), although the motion is not truly periodic the maximum amplitudes obviously occur at intervals $t = \frac{2\pi}{\omega_1'}$. The ratio of successive amplitudes of the transient is thus

$$\frac{e^{-2\pi\delta t}}{e^{-2\pi\delta\left(t + \frac{2\pi}{\omega_1'}\right)}} = e^{\frac{4\pi^2\delta}{\omega_1'}} \quad \ldots\ldots (60)$$

the natural logarithm of which serves as a measure of how fast the transient is dissipated. This logarithm is called the "logarithmic decrement" and equals $\frac{4\pi^2\delta}{\omega_1'}$. Considering only the index $i = 1$ and noting that for small δ, $\omega_1' \approx \omega_1$ it is found that

$$\text{Logarithmic Decrement} = \frac{4\pi^2\delta}{\omega_1'} \approx \frac{2\pi\delta}{n} = \pi\Delta \quad \ldots\ldots (61)$$

The critical damping and logarithmic decrement are discussed by Timoshenko[5] and Den Hartog[1] in their standard treatises.

Applying the above theory to the case of the bridge tested amounts to assuming that its deflection curve can be closely approximated by a half sine wave that its mass is uniformly distributed and that only the vertical motion of the members is of consequence. That these assumptions give results which are at least generally correct in the qualitative sense will be shown.

Damping of Span

The procedure followed in computing the damping factors Δ from the experimental date, and the system of plotting graphs of the results has been previously explained. Typical Fig. 15 shows measured and theoretical values of deflection semi-amplitude and dynamic magnifier versus forced frequency for dead load tests. Fig. 21 shows measured and theoretical phase angles versus the ratio of forced to natural frequency for the dead load condition. Table 5 is a summary of the important numerical data.

[1] pp. 49–52.
[5] pp. 32–37.
[9] pp. 32–33.

A possible source of error in the reduction of the numerical data was the use of a single set of deflection and stress factors, determined by static measurements in the frozen bearing condition. No such measurements were made after the bearings were freed. That the deflection factor did increase with the reduction of end bearing constraint is indicated by the reduction of n_o from 9.20 to 8.90, a change of 3 percent which is too great to ascribe to the simultaneous increase in Δ from 0.0933 to 0.109.

Assuming that[9] $n^2 = \frac{A}{\lambda d}$ ..... (62)

where $A =$ a constant
$d =$ theoretical dead load center line deflection
$\lambda =$ deflection factor

the new deflection factor would be given by the formula

$$\lambda' = \left(\frac{n}{n'}\right)^2 \lambda \quad \text{..... (63)}$$

where the notation is obvious. Since, as has been explained, the experimental values of k were computed by the formula

$$k = \frac{h}{\lambda d} \quad \text{..... (64)}$$

where $h =$ measured center deflection, semi-amplitude
$\lambda =$ deflection factor
$d =$ theoretical center deflection for static hammer blow

the plotted values of k for the free end bearing condition should be corrected according to the formula

$$k' = \frac{\lambda}{\lambda'} k = \left(\frac{n'}{n}\right)^2 k = \left(\frac{8.90}{9.20}\right)^2 k = 0.938\,k \quad \text{..... (65)}$$

This would reduce k_m for the free bearing condition to 8.60 and increase Δ to 0.116. However, since it was desired to correlate stress and deflection measurements, and it was felt that stress factors need not necessarily change in the same ratio as the deflection factor, no such correction was made. This was also partially justified, as a glance at Figs. 15 and 20 will bear out, by the probable error in determining n_o and k_m. This error would not affect the live load tests, since all such tests were made with end bearings frozen.

A study of the dead load figures shows that for any N, especially in the neighborhood of $\frac{N}{n_o} = 1$, the test values of k were so dispersed that their deviations from the mean cannot be entirely attributed to errors in measurement. It is believed that these deviations are properly explained on the assumption that Δ varied because of imperceptible but nonetheless significant physical changes at the connections, at the end bearings and in the track. The Δ chosen for record purposes was, for each bearing condition, near the minimum attained during the tests.

A further study of the dead load figures shows that, at least in the region near $\frac{N}{n_o} = 1$, the conditions actually approximated "viscous" or velocity damping. The experimental points did not group well enough for the presence of Coulomb or dry friction damping to be recognized by the shape of the k—N curves,[1] Fig. 15, but it is

[1] Fig. 265, p. 410, and Reference 5, Fig. 38, p. 59.
[9] pp. 22–23, and Reference 12, Art. 108.

believed that the phase angles were determined with sufficient accuracy that any strong tendency toward Coulomb damping would have been apparent from the grouping of points in the $\phi - \frac{N}{n_o}$ diagram,[1] Fig. 21.

A comparison of the experimental damping parameters with those predicted by the present AREA rating rules[12] is interesting. By these specifications, the damping constant for deep through truss spans is given by the formula

$$p = \frac{14}{L + 350} = \frac{\Delta}{2n} = \frac{\delta}{n^2} \quad \ldots\ldots (66)$$

which for the test span gives $p = 0.0309$ and agrees closely with Hunley's experimental results.[9] Using the experimentally determined values of n rather than that predicted by the AREA formula[12] the experimental and predicted damping parameters for dead load are as tabulated below

		p	Δ	δ
$n_o = 9.20$	Experimental	0.00507	0.0933	0.429
	AREA	0.0309	0.570	2.62
$n_o = 8.90$	Experimental	0.00612	0.109	0.485
	AREA	0.0309	0.550	2.45

The discrepancy between predicted and experimental results seems far too great to be caused by any peculiarity of the structure, especially since the latter was quite conventional in all respects. It is believed that the variation was due to the fact that formula (66) is based upon the results of tests made under moving locomotives, and that the locomotive spring systems contributed greatly to the damping even in the so-called "locked spring" condition.[2]

Damping of Live Load Springs

As has already been pointed out the live load spring damping coefficient, Θ, is a function of D_h and hence of the hammer blow, and of the constant spring friction force $F = \frac{\pi w_s r}{4}$ as can be seen from equation (26). In order, that for a given value of D_h, the value of Θ may be real and positive for a particular range of values of N, the value of r must not be too large. The values of r used in plotting the curves of Figs. 17 to 20, incl., are approximately the maximum attainable with the hammer blow used. Under locomotive hammer blows, larger values could have been realized. As a matter of fact, it should be realized that the use of equation (26) is itself an approximation, since it is assumed that the constant friction force can be replaced by a sinusoidal resisting force which would give the same energy dissipation per cycle. The formula cannot therefore be expected to be valid for any great range of values.

In the tests with coal cars on the span (Figs. 17 and 18) no records were taken to locate the lower critical frequency. The upper critical frequency agreed well with the calculated higher natural frequency, and in the range in which tests were taken the spring damping was well represented by either viscous damping or Coulomb friction. This can be seen on Fig. 17.

[1] Fig. 266, p. 410, and Reference 5, Fig. 40, p. 61.
[2] Ch. IX, and Reference 9, pp. 33–37.
[9] p. 56.
[12] Art. 108.

With locomotive 2244 on the span, tests were made at the lower critical frequency only. This lower critical frequency came at a value slightly less than that at which theoretical amplitudes would be sufficient to unlock the springs with the small value of spring friction allowable for real values of Θ, and gave dynamic magnifiers higher than expected. These discrepancies could be explained by a decrease in the bridge damping constant p, or by a decrease in the actual value of n from that computed by formula (13). Either or both explanations would seem more likely than the alternate one: that the springs were never locked and the lower critical speed corresponded with f_1, the lower natural frequency. This alternate explanation seems less probable because it would indicate a much larger discrepancy between calculated and actual values of the natural frequency.

With locomotive 2216 on the span, tests were run at both first and second critical speeds (Figs. 19 and 20). Insofar as the lower critical frequency is concerned the remarks made about the locomotive 2244 tests apply here as well. However, the upper critical frequency was found to be at about 14 rps., whereas the calculated second natural frequency was 8.61 rps. While this second critical frequency of 14 rps. is unimportant inasmuch as it is far above the operating range of any locomotives, the discrepancy is nonetheless disconcerting. It seems quite certain that no synchronous speed at about 8.61 rps. was missed in the tests, as the oscillator speeds were adjusted so as to search the entire range from about 3 to 15 rps. A possible explanation is as follows:

The tests at the lower synchronous speed were made with hammer blow = 96 lb. per rotor at one rps. For the higher ranges, the rotors were set for hammer blow = 37 lb., which may not have been enough to unlock the springs at the second natural frequency in the neighborhood of 8.61 rps. Since the load on the span was somewhat non-symmetrical, the second harmonic of the bridge considered as an elastic body might have been excited by a force of frequency about 14 rps., giving rise to large amplitudes sufficient to unlock the springs. However, as soon as the springs began to act the system had entirely different characteristics and natural frequencies, and the oscillations died down only to build up again as soon as the original system characteristics were restored by the locking of the springs.

In addition to explaining the apparent absence of a critical speed at about 8.61 rps. and explaining one at 14 rps., this process of build up, unlock springs, die down, re-lock, and so on would explain the vertical dispersion of the points at critical speed 14 rps. In connection with the above explanation it should be noted that the theoretical value of n, the fundamental natural frequency of the span with live load and springs locked, was 4.50 rps. This would give a theoretical second natural frequency of $2^2 \times 4.50 = 18.0$ rps. for the bridge and live load with springs locked (equation 51). Assymetry of the load and the fallacy of applying a beam formula to the case of a truss might well reduce this to the 14.0 rps. found by test.

Actual excitation of the second harmonic of the span could have been detected by the use of synchronized deflectometer at the quarter points, or by taking simultaneous strain gage readings on corresponding east and west members. Unfortunately, this was not done, largely because of the lack of deflectometers which could be reliably synchronized and of sufficient oscillograph channels to take simultaneous strain gage measurements on many members.

Analysis of these live load test results was impeded by lack of a satisfactory mathematical theory for the behavior of a truss as contrasted with a uniform beam, and by the difficulty of handling differential equations of motion involving non-viscous damping. The live load tests must therefore be considered inconclusive and unsatisfactory.

Relation of Impact in Members to Dynamic Deflection

Throughout the preceding discussion attention has been focused on the behavior of the deflection curve. More specifically, in the analysis of the dead load tests the parameter k, a function of $\frac{N}{n}$ and Δ, and equal to the ratio of dynamic center line deflection to static center line deflection has been developed. This parameter k, characterizes the oscillations of the system so that given a force F producing a static center deflection d, then the oscillating force $F \sin 2\pi Nt$ will produce center line oscillations of semi-amplitude $h = kd$. The analysis of the live load tests involves the additional parameter Θ when springs are acting. In the analysis of statically determinate structures, however, deflections are not often of primary interest. The present section will therefore attempt to show the relationship between dynamic deflection and dynamic stress.

A naïve approach to the problem would be to assume that the stresses would be magnified in the same ratio as the center deflection. On that supposition, the semi-amplitude of the dynamic stress in any member would be $h_s = k\ d_s$ where d_s is the stress that would result from a static application of the hammer blow. That this assumption is incorrect can be seen from a study of typical Figs. 15 to 20, incl., and the summary Table 5, where the actual stresses and their magnifications range from half to double what would be predicted on this basis. Considering now the dead load tests, it will be seen that the discrepancy cannot be attributed to an incorrect evaluation of Δ, since some of the points lie above the theoretical maximum curves for $\Delta = 0$. This phenomenon was observed in the earliest comprehensive tests made in this country,[6] and later in the British tests[8] where it was given the name "dynamic shear" or "dynamic bending moment"[2] which has possibly led other investigators to overlook its truly simple nature, that of "dynamic load."

Continuing to consider the dead load tests only, let a new ratio M be introduced and defined for each member by the equation

$$h_s = M\ k\ d_s \qquad (67)$$

where h_s = dynamic stress semi-amplitude
d_s = static hammer blow stress
k = dynamic magnifier based on center deflection.

M was determined empirically for each member and end bearing condition by a comparison of the actual magnification of stress at $N = n_o$ with the corresponding values of k_m. In this determination it was assumed that M was constant for any given member, an assumption which will later be proven incorrect, but sufficiently accurate for N in a suitably small neighborhood of n_o. The solid line curves of Figs. 16 to 18, 21 to 24, and 26 to 29, show Mk and $d_s\ Mk$ based upon the empirical values of M. Table 5 gives a summary of the values of k_m and $M\ k_m$.

Refer now to equation (57), the single term approximation to the deflection curve, and consider it for the case of center application of the hammer blow, that is, $c = \frac{L}{2}$.

[6] Ch. XIV.

The deflection curve is then

$$y = kd \sin \frac{\pi x}{L} \sin (2\pi NT - \phi) \quad \ldots\ldots (68)$$

For $x = \frac{L}{2}$, equation (68) of course gives the deflection which would result from a static force $Fk \sin (2\pi Nt - \phi)$ acting at $x = \frac{L}{2}$. However, for any other value of x (except $x = 0$ or $x = L$), the deflection by equation (68) is greater than would be produced by the concentrated central force. Physically, this means that the beam deflects as though the load, instead of being concentrated at the center was distributed (not necessarily uniformly) along the entire length of the span, the net result being to increase stresses near the supports and decrease stresses near the center.

Since for a uniform beam the load at any point is given by the equation

$$p(x) = EI \frac{\delta^4 y}{\delta x^4} \quad \ldots\ldots (69)$$

it would at first appear that the load distribution for an oscillating beam could be obtained by applying equation (69) to equation (57) or (68). These equations were obtained, however, by simplification of a series expansion, equation (53), and upon applying equation (69) to equation (53) the resulting series diverges for some values of x on the interval $0 \leqq x \leqq L$. It would not therefore be logical to assume that the operation could be applied with validity to the simplified equations (57) or (68). Hence resort will be had to a physical attack on the problem, based on the assumption that equations (57) and (68) adequately represent the dynamic deflection curve.

When a particle of mass m has an acceleration d, the force on the particle is md, and the particle in turn exerts an apparent or "inertia" force of equal magnitude in the opposite sense.[3] This D'Alembert force must be considered in addition to the damping and the hammer blow. The forces acting on the span are then, in addition to the reactions at the supports:

(a) the concentrated hammer blow

$$P = F \sin 2\pi Nt \quad \text{- - - - - - - - - - - - - (70)}$$

acting at $x = c = \frac{L}{2}$

(b) the distributed damping force

$$p_1(x) = -4\pi \delta m \frac{\partial y}{\partial t} \quad \text{- - - - - - - - - - - - - (71)}$$

(c) The distributed "inertia" force

$$p_2(x) = -m \frac{\partial^2 y}{\partial t^2} = 4\pi^2 N^2 m y \quad \text{- - - - - - - - - - - - - (72)}$$

Now consider the span in the position of maximum deflection

This occurs when $\sin (2\pi Nt - \phi) = 1$, or $2\pi Nt - \phi = \frac{\pi}{2} + 2V\pi$

The forces in this position are :

[3] pp. 150–153.

(a) The hammer blow at $X = C = \frac{L}{2}$

$$P = F \sin 2\pi Nt = F \sin\left(\frac{\pi}{2} + \phi\right) = F \cos \phi$$

By equation (54) $\cos \phi = k\left(1 - \frac{N^2}{n^2}\right)$ and the hammer blow is

$$P = Fk\left(1 - \frac{N^2}{n^2}\right) \qquad \text{----------} \quad (73)$$

(b) The distributed damping

$$p_1(x) = -4\pi\delta m \frac{\partial y}{\partial t} = 0 \qquad \text{----------} \quad (74)$$

(c) The "inertia" force

$$p_2(x) = 4\pi N^2 my = 4\pi^2 N^2 mkd \sin \frac{\pi x}{L} \qquad \text{---------} \quad (75)$$

If, for any span, a constant ϵ has been determined by the equation

$$d = F\epsilon \qquad \text{.....} \quad (76)$$

then equation (75) can be rewritten in terms of the amplitude of the hammer blow as

$$p(x) = 4\pi^2 N^2 mkF\epsilon \sin \frac{\pi x}{L} \qquad \text{----------} \quad (77)$$

where the subscript has been dropped since this represents the total distributed force on any element of the span.

The total distributed "inertia" load on the span is given by the integral

$$\int_0^L p(x)\,dx = 8L\pi m\epsilon FkN^2 \qquad \text{----------} \quad (78)$$

It should be noted that by equation (73) the magnitude and direction of the hammer blow when the beam is in its position of maximum deflection are functions of the phase angle and therefore of $\frac{N}{n_o}$. Thus for $N < n_o$ the hammer blow acts in the same direction as the "inertia" force. For $N > n_o$, it is in opposition. If $N = n_o$ the hammer blow vanishes as the beam passes through its position of maximum deflection.

Fig. 13 shows the deflection curve, the distributed "inertia load," the concentrated hammer blow, and the reactions at the supports. On the basis of the foregoing discussion, an analysis can be made of any particular case.

Consider the test truss with four equal panels and the load uniformly distributed. Then if the sinusoidal "inertia" load is distributed to the panel points by the usual static methods, the panel point loads are:

Panel Point	*Panel Point Reaction*
L_0	$1.25\ N^2 m\epsilon LFk$
L_1	$6.63\ N^2 m\epsilon LFk$
L_2	$9.39\ N^2 m\epsilon LFk$
L_3	$6.63\ N^2 m\epsilon LFk$
L_4	$1.25\ N^2 m\epsilon LFk$

The additional load at L_2 due to the concentrated hammer blow is $\left(1-\frac{N^2}{n_0^2}\right)Fk$.

Let the panel point L_v stress coefficients for a given member be ϵ_v. Then the stress in that member due to the dynamic loading is

$$h_s = 6.63\left(\epsilon_1+\epsilon_3\right)N^2 m\epsilon L F k+\epsilon_2\left[9.39\, N^2 m\epsilon L+\left(1-\frac{N^2}{n^2}\right)\right]Fk. \quad (79)$$

and the stress in the same member due to a static force at Fk at L_2 is

$$kd_s = \epsilon_2 Fk \quad (80)$$

The member factor is then by equation (67)

$$M=\frac{h_s}{kd_s}=1+\left[6.63 m\epsilon L\left(\frac{\epsilon_1+\epsilon_3}{\epsilon_2}\right)+9.39\, m\,\epsilon L-\frac{1}{n^2}\right]N^2 \quad (81)$$
$$= 1+CN^2$$

The coefficient C in equation (81) can be evaluated using ϵ,ϵ_1, ϵ_2 and ϵ_3. Its values for various members and natural frequencies for the dead load condition are given below:

Member	*C (n = 8.90)*	*C (n = 9.20)*
$L_0 U_1$	(+) 0.0044	(+) 0.0052
$U_1 U_2$	(—) 0.0006	(+) 0.0002
$L_1 L_2$	(+) 0.0044	(+) 0.0052
$U_1 L_2$	(—) 0.0056	(—) 0.0048

It is apparent that although M is a function of N its variation is quite slow because c is small. Consequently, if M be calculated for $N = n$, the value found will be a good approximation in a quite large interval about n.

Theoretical values of M, computed by equation (81) for the test span under dead load for the condition $N = n$, are given in Table 5. It can be seen that, as anticipated, the agreement between theoretical and measured M was good for a large range of values of N, except in the case of the lower chord members L_1 L_2 where the discrepancy was as great as 53 percent. The extreme behavior of member L_1 L_2 can be accounted for by assuming that the very low stress factor (0.440) increased under dynamic load, that is, the stringers carried a smaller proportion of the total lower chord stress than under static loading. This would also account for the difference in M for L_0 U_1 and L_1 L_2 which, by the geometry of the truss, should be identical, provided the stress factors for these two members remained constant. As further evidence of an increase in the lower chord stress factor, note that the center of gravity of the "effective lower chord" lies between the center of gravity of the stringers and that of the lower chord members. Therefore the greater the lower chord stress factor the smaller the stringer tension and consequently the lower the center of gravity of the "effective lower chord," the greater the effective depth of the truss and the smaller the top chord stress and stress factor.

TABLE 5.—SUMMARY OF TEST RESULTS—SOUTH TRUSS

Table 5 was summarized from the diagrams of deflections, stresses and dynamic magnifier curves for each member tested, such as typical Figs. 15 to 20, incl.

LOADING	FUNCTION MEASURED	n	k_m	Δ	p	δ	M k_m	M MEASURED	M_t THEORETICAL	PERCENT M OVER M_t
NO LIVE LOAD, END BEARINGS FROZEN	DEFLECTION L_2	9.20	10.70	0.0933	0.00507	0.429				
	STRESS L_0 U_1						13.50	1.26	1.44	- 12
	STRESS U_1 U_2						9.80	0.917	1.02	- 10
	STRESS L_1 L_2						18.60	1.74	1.44	+ 21
	STRESS U_1 L_2						6.70	0.625	0.593	+ 4
NO LIVE LOAD, END BEARINGS FREE, ANCHOR BOLTS TIGHT	DEFLECTION L_2	8.90	9.17	0.109	0.00612	0.488				
	STRESS L_0 U_1						11.60	1.26	1.35	- 7
	STRESS U_1 U_2						7.07	0.770	0.955	- 19
	STRESS L_1 L_2						18.90	2.06	1.35	+ 53
	STRESS U_1 L_2						5.20	0.565	0.560	+ 1
NO LIVE LOAD, END BEARINGS FREE, ANCHOR BOLTS LOOSE	DEFLECTION L_2	8.90	9.17	0.109	0.00612	0.495				
	STRESS L_0 U_1						11.35	1.24	1.35	- 8
	STRESS U_1 U_2						7.70	0.840	0.955	- 12
	STRESS L_1 L_2						18.30	2.00	1.35	+ 48
	STRESS U_1 L_2						4.80	0.525	0.560	- 6
ENGINE NO. 2216, SPRINGS LOCKED, END BEARINGS FROZEN	DEFLECTION L_2	4.50	8.10	0.0456	0.00507	0.103				
	STRESS L_0 U_1						15.10	1.86	1.33	+ 40
	STRESS U_1 U_2						11.10	1.37	1.04	+ 32
ENGINE NO. 2244, SPRINGS LOCKED, END BEARINGS FROZEN	DEFLECTION L_2	4.53	6.65	0.0459	0.00507	0.104				
	STRESS U_1 U_2						7.40	1.11	1.03	+ 8
	STRESS L_1 L_2						10.00	1.50	1.33	+ 13

From Table 5 it will be seen that for top chord members the measured M was always less than the theoretical, indicating that the stress factors varied in the manner indicated above.

It should be observed that in computing the theoretical values of M the constant ϵ was based upon the theoretical deflection of L_2 for a unit load at L_2. The introduction of the south truss deflection factor (0.784) would have given results which would have

TABLE 6.—SUMMARY OF WHEEL AND PANEL POINT LIVE LOADS
(Loads given in kips.)

		Wheel Loads												Panel Point Loads.		
Wheel or Panel Number		1	2	3	4	5	6	7	8	9	10	11	12	L_1	L_2	L_3
Locomotive	Unsprung L.L.	2.89	6.00	6.00	6.00	6.00	5.66	1.74	1.74	1.74	1.74	1.74	1.74	5.98	14.20	18.71
No. 2244	Sprung L.L.	12.31	25.56	25.56	25.56	25.56	24.14	21.26	21.26	21.26	21.26	21.26	21.26	72.90	76.39	79.65
	Total L.L.	15.20	31.56	31.56	31.56	31.56	29.80	23.00	23.00	23.00	23.00	23.00	23.00	78.88	90.59	98.36
Locomotive	Unsprung L.L.	2.89	6.00	6.00	6.00	6.00	5.66	1.74	1.74	1.74	1.74	1.74	1.74	5.98	14.20	18.71
No. 2216	Sprung L.L.	12.31	25.56	25.56	25.56	25.56	24.14	22.56	22.56	22.56	22.56	22.56	22.56	77.50	77.89	79.65
	Total L.L.	15.20	31.56	31.56	31.56	31.56	29.80	24.30	24.30	24.30	24.30	24.30	24.30	83.48	92.09	98.36
	Unsprung L.L.	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56					3.50	4.70	3.30
Coal Cars	Sprung L.L.	17.74	17.74	17.74	17.74	15.89	15.89	15.89	15.89					36.20	51.20	37.80
	Total L.L.	19.30	19.30	19.30	19.30	17.45	17.45	17.45	17.45					39.70	55.90	41.10

varied more widely from the measured values, although these results would still have been correct in the qualitative sense.

A comparison of the stress factors of Table 3 with the precent variation between the measured and theoretical values of M given in Table 5 leads to the conclusion that for the test span the method just presented for the calculation of dynamic stresses under dead load and the classical method of computing static stresses are about equally reliable for their respective purposes.

It will be noted that in the foregoing discussion the symbol n has been used in the place of n_o to represent the natural frequency of the span and its dead load. This was done because the formulas also fit the case of a bridge under uniform live load with springs locked. In the case of a non-uniformly distributed load, the values of m used in computing M can be approximated by the uniformly distributed mass which would give the same center deflection as that produced by the actual load. With this change, member factors can be computed by the above method for a bridge under live load with springs locked. The values of c for locomotives 2216 and 2244 with springs locked are given below. Data for the coal cars is not given, as no low frequency locked spring runs were made with them on the bridge.

Member	c (*Loco. No. 2216*) ($n = 4.50$)	c (*Loco. No. 2244*) ($n = 4.53$)
$L_o U_1$	+ 0.0242	+ 0.0238
$U_1 U_2$	+ 0.0026	+ 0.0025
$L_1 L_2$	+ 0.0242	+ 0.0238
$U_1 L_2$	— 0.0188	— 0.0185

Since the lower critical speed, apparently with springs locked and just before they became free, occurred under locomotive loading at about $N = 3.7$ rps., the theoretical number factors M_1 for the lower critical speed were computed from equation (81), using $N = 3.7$. These are given in Table 5. As can be seen, the agreement between theoretical and test results remained qualitatively correct but the numerical discrepancies were greater than under dead load tests.

In the case of live loads with springs acting, the forces transmitted to the span by the live load are actually spring forces rather than the inertia of masses. The sprung mass will vibrate at the same frequency as the span, moving in the same direction at lower synchronous speed and in the opposite direction at the upper synchronous speed. If the spring forces are proportional to the deflection of the truss at any point, and if the dynamic deflection curve of the truss is adequately represented by a sine curve, the spring forces will also be a sine curve. The entire bridge loading, inertia plus spring, is then represented by a sine curve, and the above theory can be used to obtain theoretical values of M. In the reduction of the present test data, this has not been done because the poor correlation between the oscillator tests at the higher critical speed with locomotives on the span, and the theory as developed by previous investigators makes the actual determination of the nature of the second critical oscillation quite doubtful.

9. Conclusions

Damping

Insofar as the bridge oscillating under dead load was concerned, the damping was very nearly viscous in effect. That is, its effect was adequately represented by a fictitious distributed force, proportional to the velocity of displacement of the element on which it acted, and opposing the motion. This approximation was especially close in the neighborhood of the natural frequency of the span. The same assumption held with good accuracy in the neighborhood of the lower critical frequency where the locomotive springs were apparently locked.

It is believed that in impact tests under moving loads, such as those upon which the 1946 AREA rating rules are based, some of the damping assigned to the span was actually contributed by the load. Also, a moving locomotive does not apply enough hammer blows to a short span to allow the oscillations to build up to their maximum. These two features combine to give an apparent damping factor much larger than the actual one when the evaluation is made from such tests under moving locomotives.

The live load oscillator tests must be regarded as unsatisfactory insofar as the evaluation of spring damping is concerned. However, the behavior of the span under locomotive loads at low oscillator frequencies indicates that at those low speeds the damping was of the Coulomb or dry friction variety.

Dynamic Deflection

A mathematical analysis of the oscillations of a beam indicates that in the neighborhood of the fundamental natural frequency of the span, and provided the hammer blow acts near the center of the span, the deflection curve is represented to a fair degree of accuracy by a half sine wave. For practical frequencies of the hammer blow, the frequencies of the higher harmonics will not be approached, and the bridge under dead load can be regarded as a single degree of freedom system. The oscillations of the center point of the span are then represented mathematically by the same equation that governs the motion of a simple sprung mass. In referring above to "degrees of freedom," it must be understood that reference is to the configuration of the span regarded as an elastic body and not to such additional degrees of freedom as may result from placing a sprung mass, for example, a locomotive with springs acting, on the bridge. The test results indicate that the above statements apply with fair accuracy to the bridge tested. Inasmuch as this was a short, deep, stiff truss, it might be expected that the mathematical analysis would apply with greater precision to longer spans having lower depth —length ratios.

Dynamic Stress

It should not be assumed that stresses will be magnified in the same ratio as deflections. For the test span, member stresses were magnified from one half to twice as much as center deflections. This phenomenon is due to the D'Alembert or "inertia" force exerted by each particle of the span, which in effect constitutes a distributed load proportional to the amplitude of oscillation at any point. Qualitatively the result is that members near the point of application of the hammer blow have lower dynamic stresses than predicted on the theory that stress is magnified in the same ratio as center deflection, while members at some distance from the point at which the hammer blow acts will be more highly stressed. Theoretical member factors for dead load tests and for live load tests for the "locked spring" frequency range were computed using an assumed deflection curve of half sine wave form. These theoretical factors were correct in a qualitative sense, and agreed well numerically for all except lower chord members. The discrepancy in the case of lower chord members is believed attributable to an increase in the lower chord stress factor under dynamic load.

There is considerable evidence to support the belief that stress factors determined by static live load measurements were not the same as those prevailing under dynamic load. This is especially true in the lower chord where the live load static stress was reduced by the axial stress in the stringers.

Utility of Future Oscillator Tests

In view of the wide discrepancy between the deflection parameters found by oscillator test and those predicted as a result of tests under moving loads, it is felt that impact tests should be conducted under the passage of trains when the object is to rate the bridge for load carrying capacity. For research into fundamentals such as the nature of the damping, the oscillator tests offer near laboratory conditions.

It has been suggested that a smaller and more portable oscillator might be used to periodically check the natural frequency of a span on the theory that deterioration would manifest itself by a change in the natural frequency. While conceding the truth of this hypothesis, it is believed that the small (3 percent) change in frequency resulting from the complete overhaul of very badly rusted end bearings indicates that changes due to deterioration would be too minute to be of value for inspection purposes.

It is possible that an oscillator of more convenient size and greater flexibility might be profitably used in the investigation of the natural frequency of structures which are so complex as to make an estimate by computation difficult or unreliable. Such an occasion might arise, for example, in the case of a tall building in which the installation of machinery was contemplated, or in the determination of critical frequencies of arches, draw bridges, continuous trusses, or other complex structures.

10. Acknowledgements

Committee 30—Impact and Bridge Stresses and the AREA are indebted to the Engineering Experiment Station of Ohio State University for initiating the construction of the oscillator and bearing one-third of its cost. Two-thirds of the cost of the oscillator, and all of the expense of performing tests and reducing the data was born by the Association of American Railroads.

The New York Central Railroad supplied the test span, loaned its mechanical deflectometers, and furnished personnel to assist in the field work.

The late J. B. Hunley, engineer of structures, New York Central Railroad, Chicago, suggested the method of mounting the oscillator, and made many useful suggestions as to its design and use.

Professors Clyde T. Morris, and P. W. Ott of Ohio State University contributed valuable suggestions as to procedures and interpretation of data.

Appendix I

A list of the more important symbols and their definitions is given below. In some cases, a tentative definition was assigned and later changed. It is believed, however, that all definitions have been clearly stated in the text and that no ambiguity will be found.

$a^2 = \frac{EI}{m}$	A constant characteristic of a uniform beam.
c, c_v	The point of application of a concentrated force P or P_v
d	Center line deflection due to the static application of a force equal to the semi-amplitude of the hammer blow.
d_s	Stress in a given member due to the static application of a force equal to the amplitude of the hammer blow.
D_h	Stress or deflection due to a static force equal to the semi-amplitude of the hammer blow at 1 rps.
E	Modulus of elasticity of the material of the span.
$f_1, f_2 \ldots f_n$	Natural frequencies of a system of n degrees of freedom, f_1 being the lowest frequency.

g	Acceleration due to the attraction of gravity.
H	Instantaneous value of a harmonic displacement of semi-amplitude h.
h	Semi-amplitude of the deflection oscillations at the center of a span.
h_s	Semi-amplitude of the stress oscillations in a given member.
I	Moment of inertia of a girder.
$k = \frac{h}{d}$	Dynamic magnification of center span deflections.
k_m	Maximum values of k.
$k_{m1}, k_{m2}, \ldots k_{mn}$	Maximum values of k for a system of n degrees of freedom, k_{m1} being the maximum occuring at the lowest frequency.
L	Length of span.
$M = \frac{h_s}{kd_s}$	Member factor.
$M_1, M_2, \ldots M_n$	Member factors in the neighborhood of the various synchronous speeds $f_1, f_2, \ldots f_n$ for a system of n degrees of freedom.
N	Frequency of the hammer blow in rps.
N_s	The "synchronous frequency," that is, the value of N for which $k = k_m$.
$n_o = \frac{\omega_1}{2\pi}$	The undamped natural frequency in rps. of the first mode of vibration of a span under dead load.
n	The undamped natural frequency in rps. of the span when loaded with dead load and total live load (springs locked).
n_1	The undamped natural frequency in rps. of the span when loaded with dead load and unsprung live load.
n_s	The undamped natural frequency of the sprung live load on its own supporting springs.
P, P_v	Concentrated forces acting on a span at $x = c$ or $x = c_v$.
$p\ (x)$	A distributed force acting on the span.
$p = \frac{\Delta}{2n} = \frac{\delta}{n^2}$	The "damping constant" of a span.
Q_i	A "generalized force."
γ_i	A "generalized coordinate."
R_1, R_2	Reactions at the supports of a simple span.
t	Time.
T	The kinetic energy of a vibrating system.
U_i	A "generalized force" due to the concentrated force F sin ωt acting at $x = c$.
V	The potential energy of a vibrating system.
W_i	A "generalized force" due to the distributed damping force on the span.
x	Distance from the origin of coordinates measured horizontically along the span.
y	Deflection of a span at the point x . . . Measured vertically downward from the dead load deflection position.
δ	The "damping coefficient" of the span.
δ_c	The "critical damping coefficient."
$\Delta = \frac{2\delta}{n} = \frac{2\delta}{\delta_c}$	The "damping factor."
$\epsilon = \frac{F}{d}$	The "deflection coefficient" by which a static force F acting at the center line must be multiplied to obtain the resulting center line deflection d.
ϵ_v	The panel point L_v stress coefficient for a given member, that is, the factor by which a force applied at L_v must be multiplied to obtain the resulting stress in the given member.
Θ	The damping coefficient of the live load springs.

ϕ_i	The phase angle between the harmonic exciting force and the displacement of the "i"-th harmonic of the deflection curve.
ϕ	The apparent phase angle between the applied force and the displacement of the span regarded as a single degree of freedom system.
m	Mass per unit length of the span.
$\omega = 2\pi N$	Circular frequency in radians per second of a harmonic exciting force.
ω_i	Circular natural frequency of the "i"-th mode of vibration of the span, with no damping.
ω_i'	Circular natural frequency of the "i"-th mode of vibration of the span with damping present.

Appendix II

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Rational Design of Sections for Short Compression Members of Steel

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Synopsis

This paper attempts to offer a rational method, based on general principles, for the design of sections of short steel columns. Diagrams showing suggested types and proportions together with general specification clauses are included.

Introduction

Failure of the main material in any compression member may be assumed to take place in one of the following ways:

1. Integral buckling of member as a whole
   a. By general flexure in a plane.*[1] (see Fig. 1.)
   b. By twisting about a longitudinal axis.[2] (See Fig. 2.)
2. Local failure
   a. By local buckling of some element of the section under action of the compressive forces in the column.[3] (See Fig. 3.)
   b. By local over-stress due to failure of bracing elements.[4]
   c. By local over-stress due to lateral displacements of main material caused by pantographic action of the lacing bars.[5]

The arrangement and proportions of material used in a column section strongly influence integral buckling strength and directly determine local buckling strength. Strength in integral buckling by bending in a plane varies inversely with column width, all other properties being constant, since bending stress depends on column width. Strength in integral buckling by twisting about the longitudinal axis depends upon the torsional rigidity of the section. Local buckling strength of the individual elements of the section depends upon the width-thickness ratio and upon the boundary support of the edges. The type of bracing suitable to support the main elements depends upon the amount of transverse shear to be carried. When this shear is very large, only continuous transverse plates are suitable. Local kinks induced in the main material by pantograph action of the lacing bars can only be prevented by the insertion of transverse ties. As the ratio of bending stress to direct stress in a compression member increases with higher working stresses, all of the above factors become increasingly important as stronger material and higher working stresses are used in design.

A well designed short column should develop an ultimate strength equal to the column area multiplied by the yield point strength of the material. Since local failure lowers the efficiency of the column as a whole, the designer should always aim for local strength at least as great as integral buckling strength. In practice this means that local failure should follow and not initiate integral failure. A study made several years ago by the author of all available reports of tests of short steel columns showed that local failure predominates, and, in fact, that designs of column sections which will produce integral column failure are still unusual.[5]

* References are to a bibliography at the end of this paper.

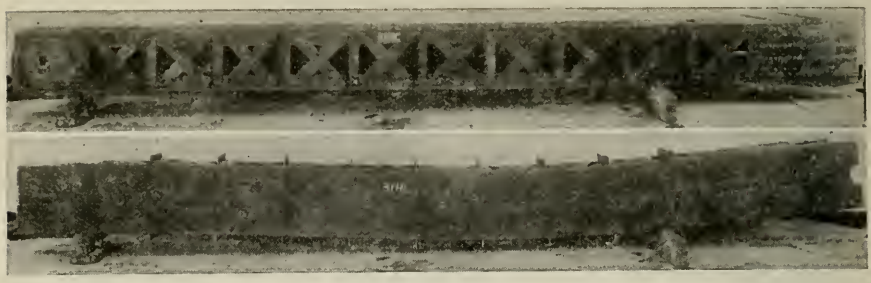


Fig. 1.—Integral Failure by Bending.

Courtesy of American Bridge Company.

Fig. 2.—Integral Failure by Twisting.
Courtesy of National Bureau of Standards.

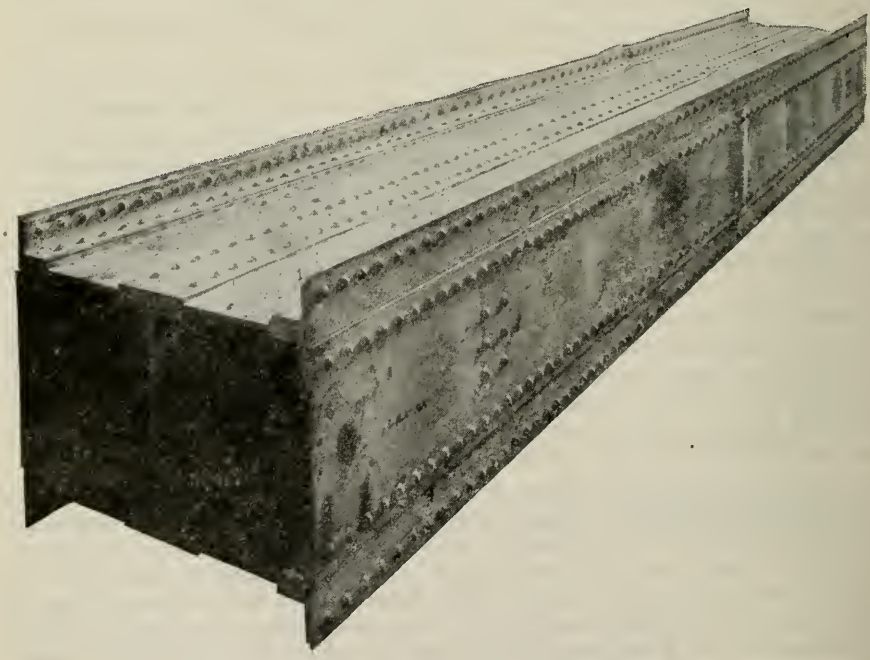


Fig. 3.—Local Plate Buckling Failure.

Courtesy of National Bureau of Standards.

This paper is concerned with the form of section and proportions of material as affecting local strength. It reviews briefly the experimental evidence available on this subject, critically examines present practice, and offers suggestions for improved types of section based upon rational procedures. No consideration is given to the strength of connections.

Local Buckling Strength of Plates and Angles

The theoretical buckling strength of plates under axial stress for certain limiting conditions of edge support is shown in Figs. 4 and 5. Comment on the implication of this theory is offered in Fig. 5.

From the standpoint of the designing engineer, the most important factor in this theory is perhaps the factor K representing boundary conditions, while the most important thing left out of the theory is probably the effect on strength of initial eccentricities in the form of short waves or kinks in the plates. The magnitude of these two important factors can only be determined experimentally.

An important consideration in making experimental investigation of the buckling strength of plates is that the edges of the plate should be fully supported against lateral displacement, as assumed in the theory, and that bending due to integral buckling of the whole member be prevented as this makes interpretation of results difficult.

The experimental results considered in this paper are all for elastic limit strengths in buckling. Ultimate strengths are often greater, but usually involve so much deformation as to impair usefulness of the member.

A. Boundary Conditions

Plates with Two Continuously Supported Edges

Two excellent experimental studies bearing directly upon this matter have been published by the National Bureau of Standards: The web plate tests for the Delaware River bridge[6] and the tests of large models of the Bayonne bridge chords.[3]

The Delaware River web plate tests were made to study the buckling strength of plates and all other factors were eliminated as far as possible. The edges of the test columns were securely supported against lateral displacement by a rigid frame.

The buckling unit stresses for these web plates are plotted in Fig. 6 and comment is offered in Fig. 7. It is important to note that the total width of the plate must be used as b for all cases if the data are to have any rational interpretation. If a less width is used, all the test results would be shifted to the left and would not fit the theoretical curves at all. Plates were all 34½ in. wide and varied in thickness from ⅜ in. to 1½ in. The steel was structural silicon steel. Each edge of the plates was enclosed between two angles 6 by 4 by ¾ in., and the whole closely stitch riveted together, providing very stiff edge supports, which are not at all to be compared with the more usual support afforded by an angle on one side of the plate edge. Even so, only in the case of the ⅜ in. plates was the simply supported strength materially exceeded. This exception represents a very unusual condition of edge support and one seldom used in practice. The total thickness of the enclosing angles was four times that of the plate, and the outstanding legs of the angles were clamped to the supporting frame.

Further evidence regarding edge support is given in the report on the test of the Bayonne bridge chord models. The yield strength of the material was 58.4 ksi.† and local buckling of a thin cover plate started below 38 ksi. The effective unsupported

† Kips (1000 lb.) per square inch.

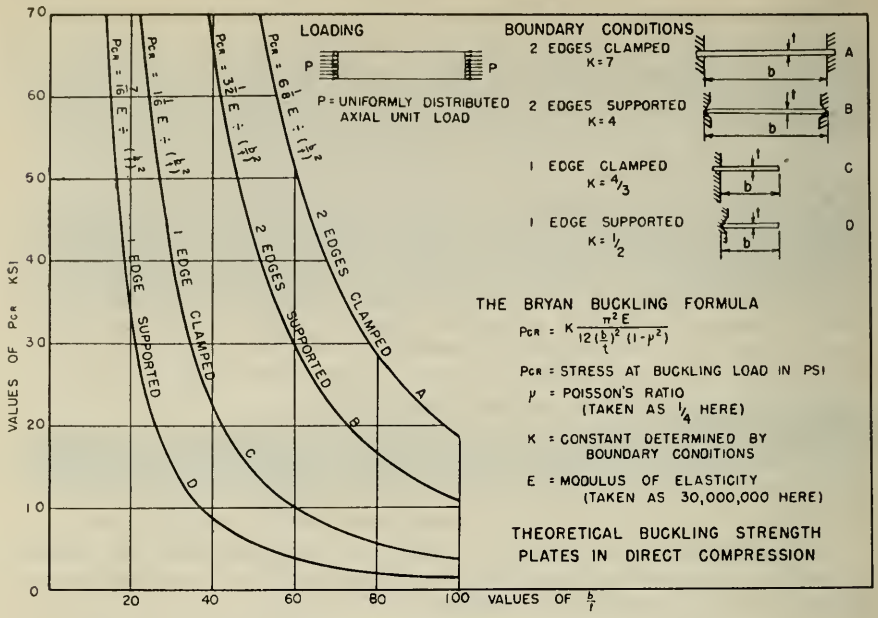


Fig. 4.—Theoretical Buckling Strength, Plates in Direct Compression.

width b can be computed from this buckling strength as 19.7 in. The plate was 21 by ⅜ in. and the distance between rivet lines was 16.88 in. (Fig. 3.)

In the Bayonne chords the rivet spacing in the edges of the cover plate was about 10.7 times the plate thickness, which was close enough to provide a supported edge condition up to a stress of 38 ksi. in axial load.

The beneficial effect of enclosing both sides of the edge of the plate by two flange angles appears to be real. It will be recalled that the five Metropolis bridge models having this arrangement tested from 5 to 10 percent higher than the five which had only single flange angles at the edges of the webs. It is not certain that this added strength was due entirely to edge support of the plate however, since the c/r^2 ratio was smaller for the first five than for the second five.[1]

From the above evidence regarding effective edge support, the following conclusions may be drawn:

1. The unsupported plate width must be taken as full width of plate for all common cases and a simply supported edge assumed.
2. Where the edge of the plate is enclosed between two heavy angles and the whole closely stitch riveted and the total thickness of the enclosing angles is five times as much as plate thickness, a clamped condition may be realized, if the angles are fastened to a rigid support.
3. The rivet spacing at edges of the plate should be decreased as a function of increasing stress. See Fig. 12 for suggested spacing.

The problem for web plates simply supported at the edges, but not clamped, and subject to direct compression, was first worked out by Bryan.* Bryan's formulas were subsequently amplified and extended by Timoshenko and others.† ‡ Perfectly elastic material of uniform strength, no initial eccentricities and axial loading are assumed.

Bryan's Formula (General Case)

$$p_{cr} = K \frac{\pi^2 Et^2}{12b^2(1-\mu^2)}$$

Where p_{cr} = unit axial stress (i.e., total load divided by total area) at which buckling or secondary failure will occur.
K = a constant, determined mathematically from dimensions of plate, conditions of loading and support of edges.
b = unsupported plate width
t = thickness of plate
E = modulus of elasticity
μ = Poisson's ratio

Bryan predicted that the plate would fail by buckling into a number of equal waves or buckles each having a length approximately equal to the unsupported width. When the elastic limit of the material is less than the computed buckling stress, the plate will fail at the elastic limit. A strip of plate having a unit width and a length b is considered. It is under direct compression from forces at the ends and is subject to restraint from the material supported at the edges of the strip. It is seen that Bryan's formula is Euler's formula multiplied by K and having the value E replaced by E over $(1-\mu^2)$, on account of the restraint offered by the supporting sides in lateral bending.

Euler's formula is $\frac{P}{A} = \frac{\pi^2 Er^2}{L^2}$ Bryan's formula is $\frac{P}{A} = K\frac{\pi^2 Et^2}{12b^2(1-\mu^2)}$

Note: $\frac{t^2}{12} = r^2$ and $b = L$.

Values of K computed for long plates, where length is several times width, are as follows:

Case A. Plate with 2 clamped edges ..... $K = 7.0$
Case B. Plate with 2 supported edges ..... $K = 4.0$
Case C. Plate with one edge clamped ..... $K = 1.33$
Case D. Plate with one edge supported ..... $K = 0.5$

Conclusions from Theory

1. Boundary conditions (actual edge support) must be determined experimentally.
2. Effect of initial kinks or waves must be determined experimentally.
3. Buckling strength varies directly as E and inversely as $(b/t)^2$.
4. The buckling load is the maximum load which the unstiffened material can carry. Material supported along the edges will carry added load up to the yield point of the material.
5. Any loading of the member above the buckling point will be accompanied by markedly increased axial strain.

* London Mathematical Society Proceedings, No. 22, p. 54, 1890.
† Timoshenko and Lessells. Applied Elasticity, p. 291–292.
‡ Timoshenko Theory of Elastic Stability, p. 324 ff.

Fig. 5.—Theoretical Buckling Strength of Web Plates and Outstanding Legs in Direct Compression.

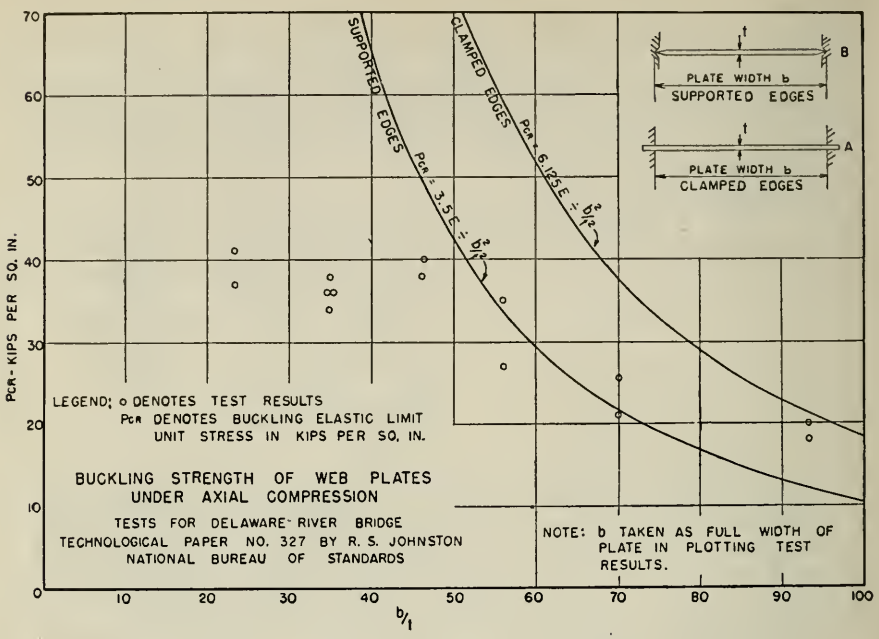

SUPPORTED EDGES
CLAMPED EDGES
PLATE WIDTH b
SUPPORTED EDGES
PLATE WIDTH b
CLAMPED EDGES
B
A
LEGEND; o DENOTES TEST RESULTS
Pcr DENOTES BUCKLING ELASTIC LIMIT UNIT STRESS IN KIPS PER SQ. IN.
BUCKLING STRENGTH OF WEB PLATES UNDER AXIAL COMPRESSION
TESTS FOR DELAWARE RIVER BRIDGE
TECHNOLOGICAL PAPER NO. 327 BY R. S. JOHNSTON
NATIONAL BUREAU OF STANDARDS
NOTE: b TAKEN AS FULL WIDTH OF PLATE IN PLOTTING TEST RESULTS.
Pcr - KIPS PER SQ. IN.
b/t

Fig. 6.—Buckling Strength of Web Plates Under Axial Compression.

4. Present practice of assuming unsupported width to be the distance between inside lines of connecting rivets is unsatisfactory and not consistent with experimental evidence.

Plate with Two Edges on Elastic Supports

This case is represented by the laced column. The Bryan formula assumes unyielding edge support. It is evident that in order to provide such support the flange angle must have a certain amount of stiffness for a given plate at a given unit stress.‡

Plate with One Continuously Supported Edge

The experimental evidence on this type is not so satisfactory, in the opinion of the author, as for the plate with two edges supported. This can probably be explained by the fact that in the tests that have been made the supported edges were not held against lateral displacement, and hence interpretation of results is less certain.

Two general investigations on steel members are available: By Roark in 1916[7] and by the ASCE Special Committee on Steel Column Research in 1933.[8]

The experimental findings appear to substantiate the theory well. The conclusions listed above for the plate with two supported edges apply here also.

‡ Note: This subject is being investigated at the present time by the author under the sponsorship of the American Institute of Steel Construction, the Inland Steel Company, and Northwestern and Purdue universities.

Conclusions From Experiment: Delaware River Bridge and Bayonne Arch Column Tests

1. Boundary Conditions

   a. Only a simply supported edge condition may be safely assumed in designing.

      It is seldom practicable or possible to secure clamped edges. See Fig. 6. The nearest approach shown experimentally was the $\frac{3}{8}$-in. web enclosed between two heavy angles on each edge and the whole closely stitch riveted together. The angles were each $\frac{3}{4}$ in. thick; in short, the total thickness of the two enclosing angles was four times that of the web. Even here the restraint was not equal to the clamped condition. (It should be borne in mind that a "clamped" edge means complete restraint against rotation as well as against displacement.)

   b. The angles or other material supporting the edges must be stiff enough to prevent displacement of the edges of the plate. Further experimental investigation is desirable here.

   c. The spacing of the rivets connecting the edges of the plate to supporting angles or other stiffening elements should not exceed about ten times the plate thickness for alloy steel.*

2. Effect of Initial Kinks or Waves in Plate

   a. The effect of initial kinks or short waves in the plate will be to lower the buckling strength materially. For the $\frac{5}{8}$-in. plates in the Delaware tests, a short wave of $\frac{1}{4}$-in. double amplitude reduced buckling strength about 23 percent.

   b. The thinner the material the greater is the probable effect of such kinks.

      1. Probability of initial kinks increases with decreasing thickness.
      2. Magnitude of kink compared with thickness of plate becomes greater with decreasing thickness.

3. Effect of Local Buckling

   It is unsafe and uneconomical to use an element with deficient buckling strength even though only part of the section is counted. The effect of local buckling of one element is to initiate local failure of the remaining elements.

* Tests of Steel Chord Members for the Bayonne Bridge. Stang, Whittemore and Sweetman. Research Paper. RP 897. National Bureau of Standards, June 1936.

Fig. 7.—Experimental Investigation of Buckling Strength of Web Plates.

B. Factors Affecting Local Buckling Strength

Initial Eccentricity

Agreement to be expected between theoretical and experimental buckling strength varies approximately with the ratio of plate thickness to plate deflections. For materials like structural steel, where the plate thickness is of about the same order of magnitude as the deflections of the buckled plate, the agreement is usually good if realistically interpreted. For thinner materials, where plate thickness is much smaller than the deflections, the variation in experimental results is usually much greater and the agreement with computed values much less consistent.

The effect of initial waves or bends in the plate is to accentuate the above relation, such waves producing a correspondingly greater reduction in strength of the thinner materials. However, for the thicker materials such as structural steel the effect is still pronounced. Thus an initial wave having an amplitude of ⅛ in. in the one of the ⅝-in. plates in the Delaware bridge models reduced the buckling strength by 23 percent. A smaller initial wave in one of the ½-in. plates reduced the strength about 15 percent. (See Fig. 6.) It is evident that a generous safety factor is desirable in selecting allowable thickness ratios for compression members.

Effect of Local Failure

The usual consequence of local failure is the local collapse, sooner or later, of the rest of the adjacent section through over stress. This is a general principle. It is strikingly illustrated in the photo of the Bayonne Chord model, Fig. 3. (Following the tests we are told that the designers thickened the plates in question.) Stated in another way, it appears undesirable to include in the column make up elements which will fail prematurely. The present practice of allowing cover plates on chord sections to be thinner than the webs is thus seen to be unscientific. The cover plates, being further from the neutral axis than the vertical webs, receive greater bending stress and should certainly be made at least as thick as the vertical webs. Furthermore, the frequent practice of making the cover plates still thinner than the specifications allow, on the plea of counting only part of the plate in the section, is obviously an invitation to local failure.

General Specifications

It is desirable to use a general specification for minimum thickness, based on theoretical buckling strength divided by a generous safety factor. This general specification should be applicable to any grade of structural steel and to any working stress. For minimum sections which never carry much stress it is obvious that a lower buckling strength (i.e., thinner material) may be used than for sections carrying allowable axial stress.

The author's suggestion for such a specification is given in Fig. 8 with specific thickness ratios recommended for present grades of structural steel. The safety factors of 4, for plates supported on two edges and of 6 for plates connected on one edge are consistent with present practice so far as minimum thickness required in average sections is concerned, provided that the total width of plate is used in computing the b/t ratios.

Strength of Transverse Bracing for Compression Elements

Shears in Short Columns

Present practice assumes that the transverse shears to be carried by the lacing and transverse bracing elements of the section arise from reversed lateral curvatures of these members under equal and opposite end eccentricities equal to $\frac{r^2}{4c}$.[9] This specified

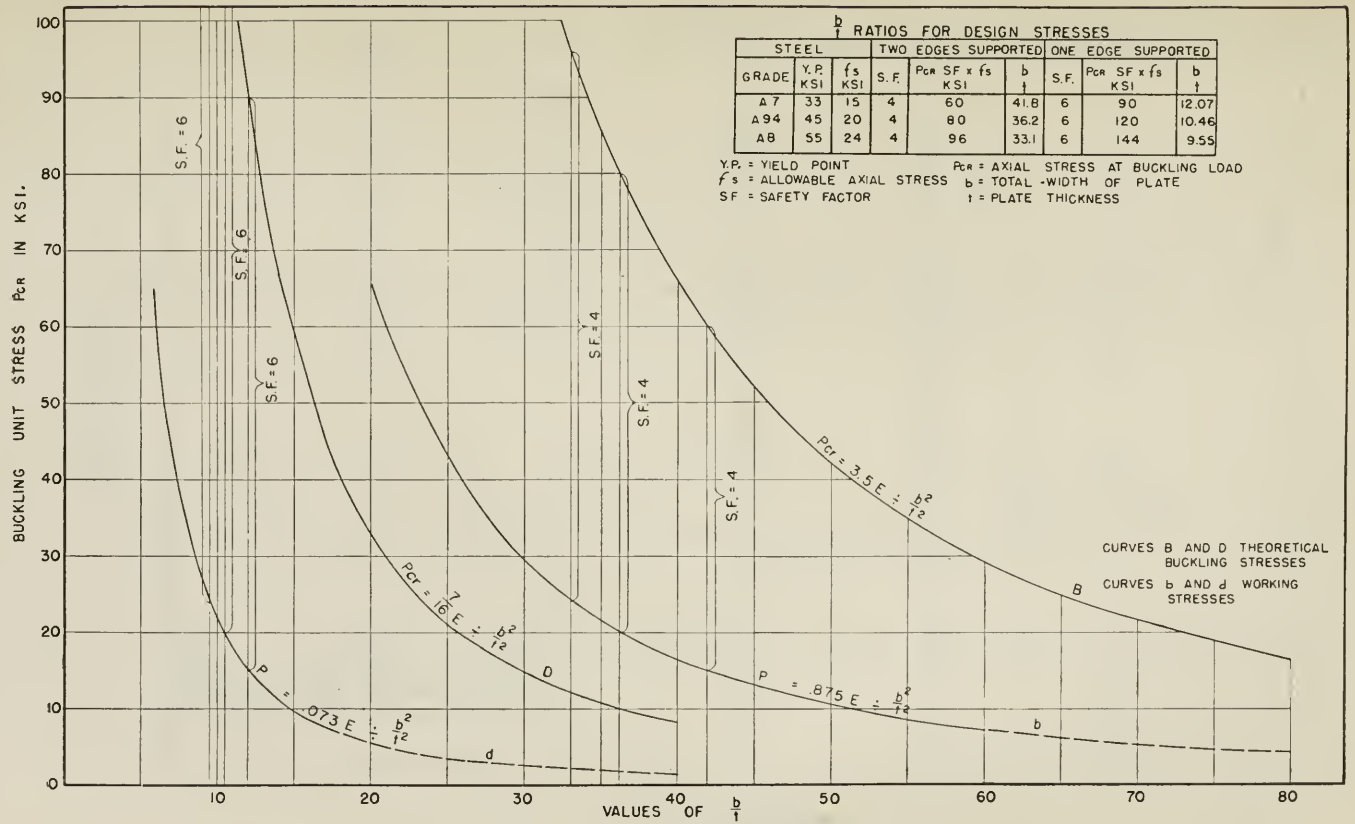

b/t RATIOS FOR DESIGN STRESSES
STEEL | TWO EDGES SUPPORTED | ONE EDGE SUPPORTED
GRADE | Y.P. KSI | fs KSI | S.F. | Pcr SF x fs KSI | b/t | S.F. | Pcr SF x fs KSI | b/t
A7 | 33 | 15 | 4 | 60 | 41.8 | 6 | 90 | 12.07
A94 | 45 | 20 | 4 | 80 | 36.2 | 6 | 120 | 10.46
A8 | 55 | 24 | 4 | 96 | 33.1 | 6 | 144 | 9.55
Y.P. = YIELD POINT
fs = ALLOWABLE AXIAL STRESS
SF = SAFETY FACTOR
Pcr = AXIAL STRESS AT BUCKLING LOAD
b = TOTAL WIDTH OF PLATE
t = PLATE THICKNESS
BUCKLING UNIT STRESS Pcr IN KSI.
VALUES OF b/t
S.F. = 6
S.F. = 4
Pcr = 3.5 E ÷ b²/12
Pcr = 1.6 E ÷ b²/12
P = .873 E ÷ b²/12
P = .875 E ÷ b²/12
B
D
b
d
CURVES B AND D THEORETICAL BUCKLING STRESSES
CURVES b AND d WORKING STRESSES

Fig. 8.—Proposed Plate Buckling Formulas for Working Stresses.

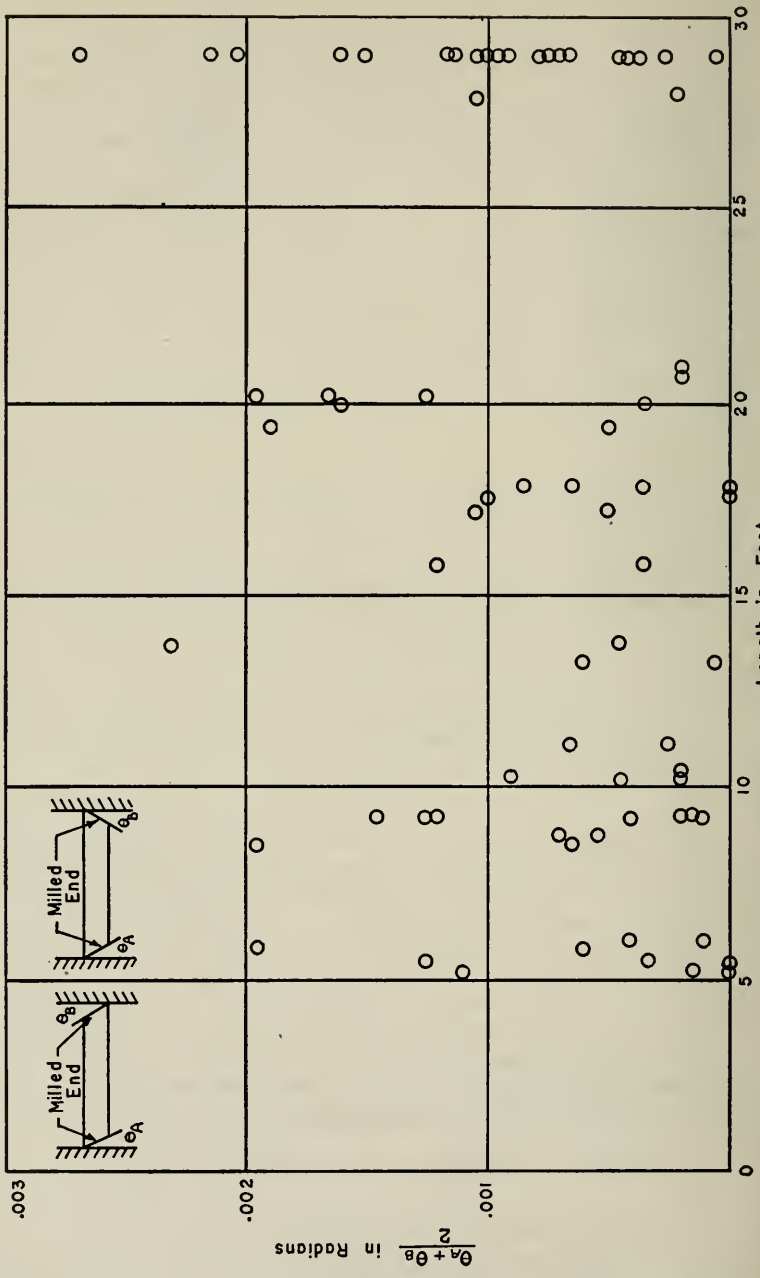


Fig. 9.—Measured Obliquities in Test Columns. See Trans. ASCE, 1933, p. 1432.

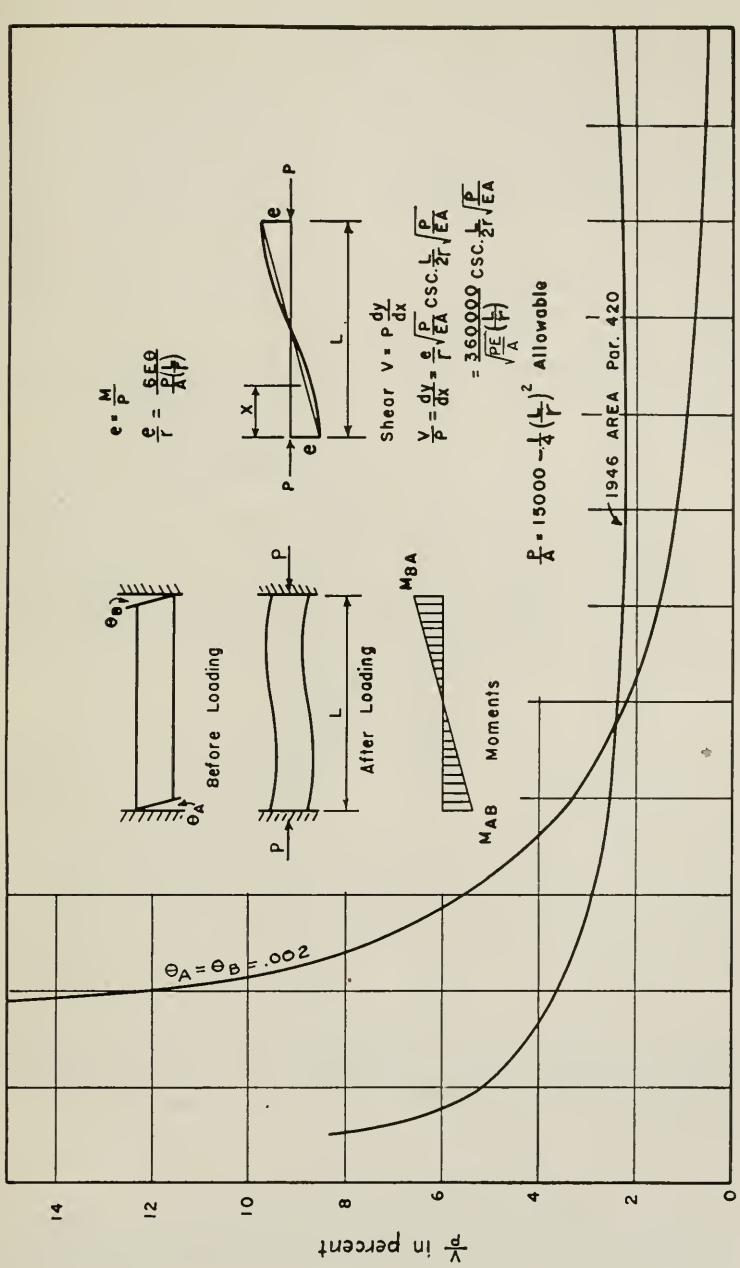

e = M/P
e/r = 6Eθ/A(L/r)
Before Loading
After Loading
Moments
Shear V = P dy/dx
y/e = dy/dx = e/r √(P/EA) csc. L/2r √(P/EA)
= 360000/√(PE/A) (L/r) csc. L/2r √(P/EA)
P/A = 15000 − 1/4 (L/r)² Allowable
1946 AREA Par. 420
θA = θB = .002
pt in percent
Values of L/r

Fig. 10.—Shears on Columns Due to Imperfect Fit of End Bearings.

shear is shown graphically in Fig. 10. It is the author's belief that in many cases actual shears on short columns are much larger than the above. This is particularly true where stress is transferred through a milled or a pin connected joint, but may arise from other causes also. This view is based upon such evidence as the following:

1. Fig. 9 shows the average out-of-square of milled ends of 39 tests columns reported by the ASCE Special Committee on Design of Steel Columns in 1935.[8] Note that initial obliquities of 0.001 radian are frequent and that in 13 cases the figure is 0.002 or greater.
2. Column 5 of the Equitable building, in Des Moines, Iowa,[10] showed stresses corresponding to a rotation of the lower end of the column through an angle of more than 0.001 radian.
3. Column 4 of the American Insurance Union Building, at Columbus, Ohio,[11] showed stresses corresponding to a rotation of the lower end of the column through an angle of about 0.0014 radian.
4. Measurements in 2 bridges of fit between 6 large trunnion columns and grillages showed initial end obliquities of the column ends varying from 0.001 to 0.003 radian.[12]

To illustrate the shears produced by such initial end obliquities the curve in Fig. 10 is given.

Since the proportioning of lacing in short columns to take shears of such magnitude is impracticable, the author would propose the specifying of one or more web plates at right angles to the main vertical webs. There are a number of other well recognized reasons why dependence for ultimate strength of a short compression member should not rest upon lacing alone.[6] This use of one or more transverse web plates has long been followed by many prominent designers. It is not an innovation. In modern practice the perforated plate is used extensively, instead of lacing.

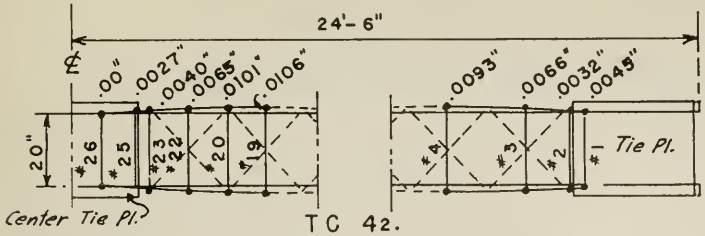
Perforated Plates with Two Edges Continuously Supported

The unknown quantities in the buckling strength of these plates are the effects, on buckling and shear strength, of size and shape and spacing of holes or perforations in plates with fully supported edges.

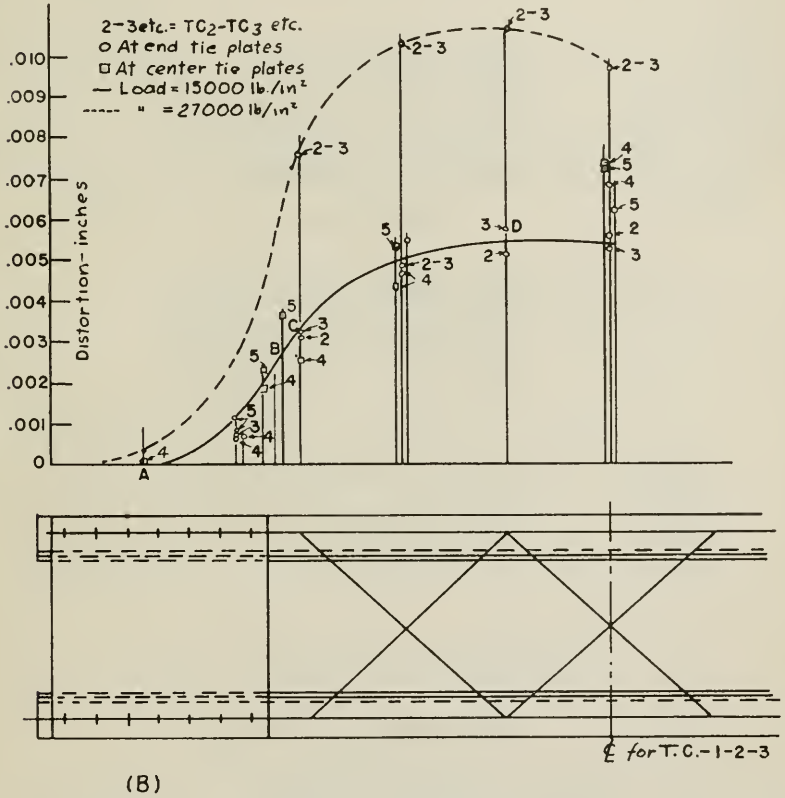
A number of careful and excellent studies on this matter have been published by the National Bureau of Standards.[13] These studies, however, are not conclusive at the present time, since the plates were tested as parts of columns having L/r values up to 70 or more and not as parts of columns having all lateral movement prevented as was the case with the Delaware River web plate test models. In short, due to column action (i.e., lateral bending) it is difficult to know at what actual unit stress the perforated plates buckled, or how much more load they might have carried had lateral movement of the column been prevented. Most of these specimens, including the solid plate control specimens, are listed as failing at an axial unit stress below the yield point of the material. Also, very little shear appears to have been carried by these plates since the columns were carefully centered in the testing machine. The studies are not yet completed and it is probable that some of these questions will be cleared up in later reports.

Used as transverse webs, perforated plates are intended both to carry the transverse shears on the column, and to contribute to the column cross section.

Present practice is to make the perforations ovaloid in shape and to space them rather widely along the member, and as a result considerable axial stress is picked up by the central part of the plate in the region between perforations. This is particularly the case when the spacing between perforations is large and when the plate is thicker than the minimum allowable.



(A)



(B)

Fig. 11.—Pantograph Action of Lacing.

The Quebec Bridge. Final Report of Government Board of Engineers, pp. 207, 208.

(A) Spread of Ribs: Measurements taken at gage 320 = 20,240 psi. axial stress.

(B) Distortion of ribs due to lattice action.

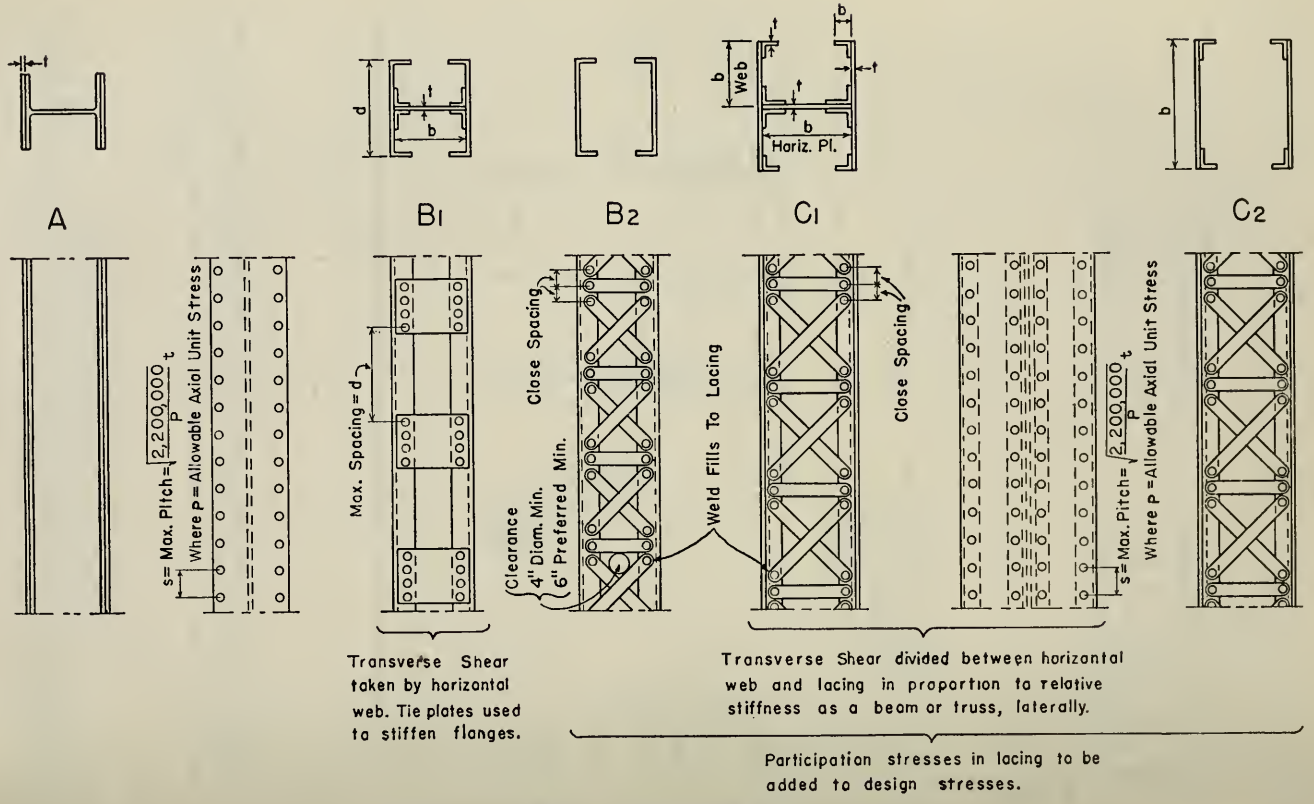
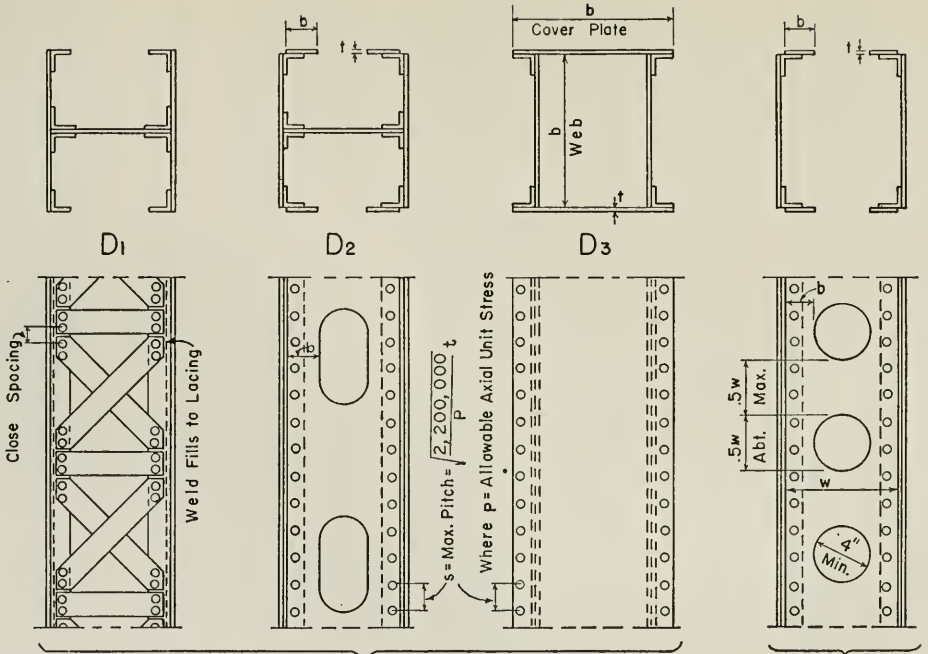

A
B1
B2
C1
C2
Web
Horiz. Pl.
Max. Spacing = d
Close Spacing
Clearance
4" Diam. Min.
6" Preferred Min.
Weld Fills To Lacing
Close Spacing
s = Max. Pitch = √(2,200,000/p) t
Where p = Allowable Axial Unit Stress
Transverse Shear taken by horizontal web. Tie plates used to stiffen flanges.
Transverse Shear divided between horizontal web and lacing in proportion to relative stiffness as a beam or truss, laterally.
Participation stresses in lacing to be added to design stresses.

Fig. 12.—Proposed Column Sections and Proportions.



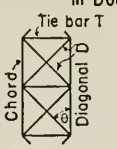
Transverse shear divided between horizontal plates or between horizontal plates and lacing in proportion to relative stiffness as a beam or truss, laterally.

Particpation stresses in lacing to be added to design stresses

Section proposed for Experimental study

Note: Should not be used unless tests prove section suitable.

Participation Stresses in Double Lacing



Stresses:

$$d = \frac{f_s \cos^2\theta}{1+2\frac{D}{T}\sin^3\theta}$$

$$t = 2\frac{D}{T} d \sin\theta$$

When $\theta = 45°$

$$d = \frac{f_s}{2+\frac{D}{T}\sqrt{2}}$$

$$t = \frac{D}{T}\sqrt{2}\, d$$

Where: f_s = Unit Stress in Column
d = " " " Diagonal
t = " " " Tie Bar
D = Gross Area of Diagonal
T = " " " Tie Bar

Fig. 13.—Proposed Column Sections and Proportions.

This means that the neutral axis of the member will not be a straight line, but will move up and down along the member in the following cases:

1. Where a solid cover plate is used on top and a perforated plate below.
2. Where two perforated plates are used and the perforations of the top and bottom plates are not opposite but are staggered along the member.

The above is another way of saying that unnecessary bending is being induced in the member.

The first principle of design of a compression member is to eliminate eccentricity as far as possible, and the author would propose the following modifications of present practice regarding these plates:

1. The perforations should be made circular in shape, and spaced closely together along the member. Thin rather than thick plates should be used.
2. Complete symmetry should be assured. If two perforated plates are used, the perforations should be exactly opposite and equal in size.

The first provision will reduce to the minimum the primary stress carried by the central part of the plate. The desirability of the second is plain. These relations are summarized in Fig. 13. In the author's opinion more experimental information than is now available is needed, including study of the proposals he makes here.

Realistic Lacing Practice

One of the most common sources of weakness in heavily loaded short columns is the sharp bending of main material induced by the accordion or pantograph action of double lacing. As the column shortens under load, the lacing forces the main ribs out of line laterally except where splice plates, tie plates, or other restraining elements prevent this movement. Sharp kinks are forced into the main material, with resulting loss of strength due to local failure. Fig. 11 shows careful measurements of this action taken by Professor MacKay in testing the nickel steel models for the Quebec bridge. MacKay's strain measurements show the local stresses to be high. He found that most of the short column test models failed locally due to this action. Study of other column investigations shows the same type of local failure to be very prevalent.[5] The placing of transverse ties at intersections of double lacing effectively prevents this local racking and directly raises the column capacity as was proved by the tests of Cartlidge's models of the Metropolis bridge.[1]

The use of ties will increase the stresses in the lacing by forcing the diagonals to "participate" in the main column stresses; and when such ties are used, the "participation" stresses should be included in the design of the lacing. See Fig. 13. This increase of lacing stresses beyond present practice is more apparent than real, however, since the lacing adjacent to tie plates and splice plates suffers considerable participation stress at the present time, as some of the strain measurements show.

To eliminate this source of weakness, the author proposes the use of transverse ties at lacing intersections on all highly stressed short columns.

Symmetry

As the aim of the designer of the compression member is to centralize the load and eliminate all possible bending, it is suggested that sections be made completely symmetrical about both axes in all respects. The unsymmetrical member in general is an invitation to local failure of one side before the other in the opinion of the author.

Suggested Questions Requiring Experimental Study

1. Relation between various types of edge support and buckling strength of plate:
   a. Rivet spacing in edge of plate.
   b. Effect of enclosing edge of plate between two flange angles.
2. More information on buckling strength of perforated plates:
   a. Buckling strengths of plates having ovaloid and circular perforations widely spaced with edges held against lateral support.
   b. Buckling strengths of plates having circular perforations closely spaced when tested with edges held against lateral support.
3. Tests to destruction of box shaped columns having perforated cover plates with:
   a. Unsymmetrical sections with solid cover plates on one side and perforated plates with ovaloid openings widely spaced on the other.
   b. Symmetrical sections with plates having ovaloid openings widely spaced.
   c. Symmetrical sections with plates having closely spaced circular perforations.

Proposed General Specification Provisions for Short Columns

Form of Section

Sections of compression members shall be symmetrical about both center lines. If perforated plates are used, the perforations shall be identically shaped and symmetrically arranged.

The vertical webs shall be connected by one or more solid or perforated plates when:

1. The member carries computed bending stress.
2. The L/r of the member is less than 50.

Where practicable, each edge of each plate shall be enclosed between two flange angles.

Local Buckling Strength

To provide local buckling strength, the width-thickness ratios for plates and outstanding flanges and legs of angles, shown in Table 1, shall be provided.

The effective area of a perforated plate shall be the net area on a section through the center of the perforation.

No plate or element shall be used which does not fulfill the above thickness requirements.

The pitch of rivets along supported edges of a plate shall not be less than the following:

$$s = \sqrt{\frac{2{,}200{,}000}{p}}\, t \qquad \text{where } s = \text{rivet spacing c—c}, \quad p = \text{axial unit stress in the plate}$$

Lacing

Where lacing is used on main compression members of mild steel having an L/r less than 65, and on all main members of alloy steel, the lacing shall be double and there shall be tension ties at the lacing intersections at chord connections. The participation stresses in such lacing shall be added to the other specified shear stresses in designing the lacing. The connections with chords shall be made as compact as possible. In general, lacing shall be avoided as far as possible.

TABLE 1.—MAXIMUM b/t RATIOS

Member	*Steel*	*Unit Stress Carried*	*Plate Supported on Two Edges*	*Outstanding Legs of Angles and Plates Supported on One Edge*
Main Members	All structural steels	Any unit stress	$b/t = \sqrt{\frac{26,250,000}{f_s}}$	$b/t = \sqrt{\frac{2,187,500}{f}}$
	Structural carbon steel	15 ksi.	$b/t = 42$	$b/t = 12$
	Structural silicon steel	20 ksi.	$b/t = 36$	$b/t = 10.5$
	Structural nickel steel	24 ksi.	$b/t = 33$	$b/t = 9.5$
Main and bracing members	All steels	Any unit stress	Maximum $b/t = 60$ In any case	Maximum $b/t = 16$ In any case

Where:

f_s = computed axial unit stress in member.
t = thickness of plate or angle.
b = plate or angle width defined as follows:

Plate supported on two edges.

b = Total width of plates connected at both edges.
b = Half width of plates connected at both edges and at center.

Outstanding leg of angle or plate supported on one edge.

b = Total width of outstanding leg of angle.
b = Half width of flange of rolled beams unsupported on outside edges.
b = Distance from edge of hole to outside edge of plate in a perforated plate.

Perforated Plates

$$\text{Min. } t = \frac{w}{50} = \frac{b}{12} \text{ for structural carbon steel.}$$

$$= \frac{w}{44} = \frac{b}{10.5} \text{ for structural silicon steel.}$$

$$= \frac{w}{40} = \frac{b}{9.5} \text{ for structural nickel steel.}$$

Where w = total width of plate.

Proposed Column Sections and Proportions

The proposed types and proportions of short column sections are illustrated in Figs. 12 and 13.

Comments on Application of Proposals

The practical effects of the application of the proposals of this paper would be:

1. Increased capacity of compression members through reduced local failure.
2. Eventual economy through the use of higher designing stresses, when experiments have shown that local failure has been eliminated.
3. Economy in minimum section members since buckling strength would be proportional to stress.
4. The elimination of lacing in many short members, a process already begun in some quarters. In many cases, the solid wide flange beam is the natural solution here.[14]
5. Replacement of the conventional cover plated top chord section by narrower members, since narrow horizontal webs are more easily spliced into gussets than are wide plates.

In support of the practicability of the proposals advanced, the author would plead the following:

1. The ten models of the Metropolis bridge columns, designed by Cartlidge, were unique in the following respects:[1]
   a. They failed by integral flexure and without local failure prior to general buckling failure.
   b. They all had central solid plate webs at right angles to the vertical webs.
   c. They all had adequate lacing with transverse ties at the intersection of the diagonals.
   d. The strength and efficiency of the members was all quite high.
2. Solid box columns, if adequately proportioned, are generally much more free of local failures than sections tied together with lacing.[15, 16, 17]
3. Where comparative tests on short columns have been made, the introduction of a central solid plate at right angles to the main webs has shown marked increase in ultimate strength.[18]
4. In the design of a large highway cantilever bridge the author used all of the proposals suggested here and the contractors found them eminently satisfactory and workable.[19]

Finally, it should be said that while eminent engineers once considered it to be impossible to design short columns which would develop ultimate capacity without prior local failure,[20] the Metropolis columns demonstrated, once and for all, that properly designed short columns will fail as a unit.

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MEMOIRS

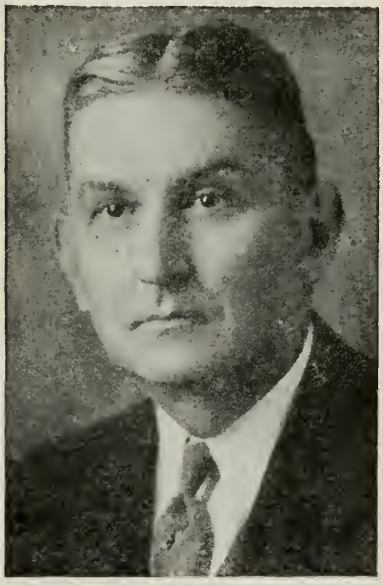
MEMOIR

William Dollison Faucette

Died May 19, 1947

William Dollison Faucette, executive representative of the Seaboard Air Line Railroad Company, and chairman of that road's Committee of Research and Planning, died on May 19, 1947, at his home in Norfolk, Va., after an illness of several weeks. He is survived by his wife, Mrs. Belle Nash Faucette, three daughters, Mrs. W. E. Black, Mrs. J. L. Weller, Jr., Miss Belle Dollison Faucette, and three grandchildren, all of Norfolk, Va. Mr. Faucette's mother, Mrs. Florence Dickens Willcox, died on June 12, 1947.

Mr. Faucette was born in Halifax, N. C., June 27, 1881, the son of Charles William and Florence Relinda (Dickens) Faucette. He attended North Carolina State College at Raleigh, N. C., from which he received the degrees of B. E. in 1901; C. E. in 1910; and D. Sc. in 1929.



William Dollison Faucette

His entire professional career comprised 46 years' continuous service with the Seaboard Air Line Railroad. Shortly after being graduated from college in 1901, he was engaged in railroad field work for five years with headquarters at Savannah, Ga., followed by a four-year service from 1906 to 1910 as assistant engineer in the chief engineer's office, then located at Portsmouth, Va. From 1910 to 1912 he was assistant to the president with headquarters at New York and, in 1913, when only 32 years of age, he was appointed chief engineer of the entire Seaboard system, which position he held until 1944, when he was appointed executive representative. In 1946, he was assigned additional duties as chairman of the railroad's Committee of Research and Planning.

Mr. Faucette became a member of the American Railway Engineering Association in 1914 and during his long and active membership served on several important committees of the Association, including Committee 22—Economics of Railway Labor in 1920; Committee 25—Waterways and Harbors from 1932 to 1946; and Committee 26—Standardization from 1922 to 1926. He was a director of the AREA in 1923, served as vice-president from 1926 to 1928, and as president of the Association for the year 1928–1929. He was appointed a member of Committee 20—Uniform General Contract Forms in 1916 and was a member until his death, serving as chairman of that Committee from 1921 to 1926. He was a member of Committee 24—Cooperative Relations with Universities from 1924 to 1933 and from 1940 to 1947. All of his work on committees was outstanding. He was always active in increasing the Association's membership. His earnestness, zeal and interest in all matters will long be remembered.

Mr. Faucette was a member of several other engineering organizations, including the American Society of Civil Engineers, the North Carolina Society of Engineers, and the Engineers Club of Hampton Roads. He was a past-president of the Virginia Section of ASCE and maintained an active and interested membership in all of these societies.

Notwithstanding his exacting duties with the railroad, Mr. Faucette was also associated with a large number of other organizations. For many years he was a trustee of the University of North Carolina, and later a member of the university's Executive Committee. He also was a member of the Norfolk City Council Committee on Higher Education; a member of the board of directors of the Norfolk Central Y. M. C. A. and vice-president of the Norfolk Travellers Aid Society. He was chairman, Zone 3, Committee on Waterway Projects of the Association of American Railroads, a member of its Special Committee on Grade Crossing Protection and Elimination, a member of its Committee for the Study of Transportation, chairman of the Joint Committee on Metric System of that association and represented it on the Council of the American Institute of Weights and Measures.

Mr. Faucette was a member of Phi Kappa Phi and Tau Beta Pi fraternities, a vestryman in St. Andrew's Episcopal Church of Norfolk, a Mason, and past-president of the Norfolk German Club, of which he was an ardent supporter. He was also a member of the Norfolk Yacht and Country Club and the Virginia Club of Norfolk.

In the death of Mr. Faucette the American Railway Engineering Association, as well as the host of friends which he had in this and other organizations, has suffered a severe and grievous loss. All of those associated with Mr. Faucette recognized his professional ability and attainments, sound judgment and broad, balanced viewpoint, together with a fine human and cooperative spirit which placed him as an outstanding leader among men. His loyalty and devotion to anything with which he was associated was always intense and he met each responsibility with a steadiness and perseverance characteristic of him. No man could work more devotedly and few could succeed so well in bringing the best out of those with whom he worked. His consideration for and interest in others, his fine democratic way and friendly manner won him many friends who will long cherish his memory.

J. B. Akers, *Chairman,*
G. D. Brooke
E. M. Hastings
F. R. Layng
W. D. Simpson
Committee on Memoir.

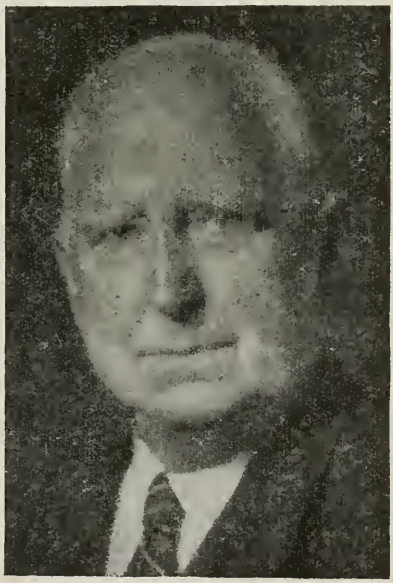
MEMOIR

George Watson Kittredge

Died August 22, 1947

George Watson Kittredge, son of Joseph and Henrietta Frances (Watson) Kittredge, was born in North Andover, Mass., December 11, 1856 and died at his home in Yonkers, N. Y., on August 22, 1947 in his 91st year.

He was educated in the public schools of North Andover and was graduated from the Massachusetts Institute of Technology in 1877, with the degree of B. S. in Civil Engineering. He married Georgia Davis on October 17, 1888, who died December 29, 1921. A daughter, Mary Henrietta Kittredge (Mrs. Denman McNear), and a son, George Davis Kittredge, survive him.



George Watson Kittredge

Upon graduation he was engaged in private engineering practice in eastern Massachusetts and was with the South Boston flats improvement during 1878 and 1879. He began his railroad career in 1880, serving in the engineer corps of the Pittsburgh, Cincinnati & St. Louis Railroad from 1880 to 1883, and from 1883 to 1890 held the position of division engineer, maintenance of way for different divisions of the Pennsylvania Lines West. During this period and for several years following he served as consultant chief engineer for the Louisville & Jeffersonville Bridge Company.

In 1890 he joined the present New York Central System as assistant chief engineer of the Cleveland, Cincinnati, Chicago & St. Louis Railway, and from 1891 to 1906 was its chief engineer.

On April 9, 1906, he was transferred to New York City as chief engineer of the New York Central Railroad, Buffalo and East, which position he held until his retirement in 1927. During this time he was also chief engineer of the Hudson River Connecting Railway and other subsidiary lines of the New York Central east of Buffalo.

Among the larger projects progressed during his period of service as chief engineer were the Grand Central Terminal Improvement; the electrification of the Hudson division from Grand Central to Croton and of the Harlem division from Grand Central to North White Plains; four tracking of sections of the Hudson division; the Castleton cutoff with the large classification yards at Selkirk; and many passenger and freight terminal improvements.

He was designated as a member of a committee consisting of engineering representatives from the various component railroads of the New York Central Lines for the purpose of considering engineering standards and practices.

He was elected second president of the American Railway Engineering Association (organized in 1899) and served two terms, 1901–1902 and 1902–1903. He also served as vice-chairman of Committee 3—Ties, from 1900–1901; member of Committee 4—Rail, from 1909–1913; Committee 18—Electricity, from 1909–1924, being chairman from 1909–1913; and Committee on Stresses in Railroad Track from 1913–1941. He was elected an honorary member of the AREA in 1933.

He was a member of the American Society of Civil Engineers, serving as director from 1908 to 1910, and as vice-president during 1917 and 1918. In 1931 he was elected an honorary member of the Society. From 1911 to 1927, he was vice-president of the Eastern Railroad Association, and a member of its executive committee. He was active in committee work and on the Library Board of United Engineering Trustees. In 1931 he was appointed a member of a committee to assemble authentic information on engineering opportunities in Russia for members of the profession in this country.

After his retirement in 1927, he maintained an office as consulting engineer in New York City and acted as consulting engineer for railroads in the United States and Canada.

He was a member of the New York Society of the Order of Founders and Patriots of America; the Society of Mayflower Descendants; the American Association of the Advancement of Science and the Fortnightly Club for the Study of Anthropology.

Mr. Kittredge was greatly interested in the development and success of the American Railway Engineering Association; he was a charter member and in addition to being active in committee work, he encouraged the younger engineers to state their experiences and opinions on the floor of the annual conventions; he well knew that such activity was the surest way to produce valuable members for the Association and increase their personal knowledge of railroad work. At 90 years of age his interest in engineering was unabated after 70 years of experience.

Edwin F. Wendt, *Chairman,*
R. E. Dougherty
G. J. Ray
Committee on Memoir.

American Railway Engineering Association

CONSTITUTION

Revised to June 15, 1948

Article I

NAME, OBJECT AND LOCATION

1. Name

The name of this Association shall be the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

2. Object

The object of the Association shall be the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

3. Means to be Used

The means to be used for this purpose shall be:

(a) The investigation of matters pertaining to the object of the Association through Standing and Special Committees.

(b) Meetings for discussion of reports and papers.

(c) The publication of papers, reports and discussions.

4. Conclusions

The conclusions reached shall be recommendatory.

5. Location

The office of the Association shall be located in Chicago, Illinois.

Article II

MEMBERSHIP

1. Classes

The membership of this Association shall be divided into five classes: Members, Life Members, Honorary Members, Associates and Junior Members.

2. Qualifications

A. GENERAL

(a) An applicant to be eligible for membership in any class other than that of Junior Member shall be not less than twenty-five (25) years of age.

(b) To be eligible for membership in any class, or for retention of membership as a Member, an Associate or a Junior Member, a person shall not be engaged directly or primarily in the sale to the railways of appliances, supplies, patents or patented services.

(c) The right to membership shall not be terminated by retirement from active service.

(d) In determining the eligibility for membership in any class, graduation in engineering from a school of recognized standing shall be considered as equivalent to three years of active practice, and satisfactory completion of each year of work in such school without graduation shall be considered as equivalent to one-half year of active practice.

B. Member

A Member shall be:

(a) An engineer or officer in the service of a railway corporation that is a common carrier, who has had not less than five years' experience in the location, construction, operation or maintenance of railways.

(b) A Professor of Engineering in a university or college of recognized standing.

(c) An Engineer or Member of a public board or commission who in the discharge of his regular duties deals with railway problems.

(d) An editor of a trade or technical magazine who in the discharge of his regular duties deals with railway problems, and who has had the equivalent of five years' engineering or railway experience.

(e) A consulting engineer, engaged in private practice, or an engineer in his employ, who has had the equivalent of five years' engineering experience.

C. Life Member

A Life Member shall be a Member who has paid dues for thirty-five (35) years, or who has been retired under a recognized retirement practice and has paid dues for not less than twenty-five (25) years.

D. Honorary Member

(a) An Honorary Member shall be a person of acknowledged eminence in railway engineering or management.

(b) The number of Honorary Members shall be limited to ten (10).

E. Associate

An Associate shall be:

(a) An Engineer of a railway which is essentially an adjunct of an industry or which is used primarily to transport the products and materials of an industry to and from a railway which is a common carrier.

(b) A person qualified by training and experience to co-operate with Members in the object of this Association but who is not qualified to become a Member.

F. Junior Member

(a) A Junior Member shall be not less than twenty-one (21) years of age and shall be an engineering employee of a railway corporation who has had not less than three (3) years of experience in the location, construction, operation or maintenance of railways.

(b) His membership in this Association shall terminate at the end of the calendar year in which he becomes thirty (30) years of age.

(c) He may make application for membership other than as a Junior Member at any time when he becomes eligible to do so.

3. Transfers

The Board of Direction shall transfer from one class of membership to another, or may remove from membership any person whose qualifications so change as to warrant such action.

4. Rights

(a) Members and Life Members shall have all the rights and privileges of the Association.

(b) Honorary Members shall have all the rights and privileges of the Association except those of holding elective office, provided, however, that Members or Life Members who are elected Honorary Members shall retain all the rights and privileges of the Association.

(c) Associates and Junior Members shall have all the rights and privileges of the Association, except those of voting and holding elective office.

Article III

Admission, Resignation, Expulsion and Reinstatement

1. Charter Membership

The Charter Membership of this Association consists of all persons elected to membership before March 15th, 1900.

2. Application for Membership

(a) A person desirous of membership in this Association shall make application upon the form provided by the Board of Direction. In the event that Junior Membership is desired, the application shall so state.

(b) The applicant shall give the names of at least three Members of this Association to whom personally known. Each of such Members shall be requested by the Secretary of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's fitness or otherwise for membership.

(c) If an applicant is not personally known to three Members of this Association, the names of at least three well known persons engaged in railway or allied professional work to whom personally known shall be given instead. Each of such persons shall be requested by the Secretary of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's fitness or otherwise for membership.

(d) No further action shall be taken upon the application until replies have been received from at least three of the persons named by the applicant as references.

3. Election to Membership

(a) Upon completion of the application in accordance with Section 2 of this Article the Board of Direction through its Membership Committee shall consider the application and make such investigation as it may consider desirable or necessary.

(b) Upon completion of such consideration and investigation, each member of the Board of Direction shall be supplied with all the information obtained, together with the recommendation of the Membership Committee as to the class of membership, if any, to which the applicant is eligible and the admission of the applicant shall be canvassed by letter ballot among the members of the Board of Direction.

(c) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (b) of this Article, a two-thirds affirmative vote of the entire Board of Direction shall be required for election.

(d) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (c) of this Article, a unanimous affirmative vote of the entire Board of Direction shall be required for election.

4. Subscription to the Constitution

A person elected to membership in this Association shall subscribe to its Constitution on the form prescribed by the Board of Direction. If this provision has not been complied with within six months of notice of election the election shall be considered null and void.

5. Honorary Member

A proposal for Honorary Membership shall be endorsed by ten or more Members of the Association and a copy furnished each member of the Board of Direction. The nominee shall be declared an Honorary Member upon receiving a unanimous vote of the entire Board of Direction.

6. Resignation

The Board of Direction shall accept the resignation, tendered in writing, of any person holding membership in the Association whose obligations to the Association have been fully met.

7. Expulsion

Charges may be preferred in writing by ten or more Members against a person holding membership in the Association. The person complained of shall be served with a copy of such charges and shall be given an opportunity to answer them to the Board of Direction. After such opportunity has been given, the Board of Direction shall take final action. A two-thirds affirmative vote of the entire Board of Direction shall be required for expulsion.

8. Reinstatement

(a) A person having been a Member, an Associate or a Junior Member of this Association and having resigned such membership while in good standing may be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

(b) A person having been a Member, an Associate or a Junior Member of this Association and having forfeited membership under the provisions of Article IV, Section 3, may, upon such conditions as may be fixed by the Board, be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

Article IV

Dues

1. Entrance Fee

(a) An entrance fee of ten dollars ($10.00) shall be payable to the Association with each application for membership other than Junior Membership. This sum shall be returned to an applicant not elected.

(b) No entrance fee shall be payable to the Association on account of Junior Membership.

2. Annual Dues

(a) The annual dues for each Member and each Associate shall be fifteen dollars ($15.00).

(b) The annual dues for each Junior Member shall be seven dollars and fifty cents ($7.50).

(c) Life Members and Honorary Members shall be exempt from the payment of dues.

3. Arrears

A person whose dues are not paid before April 1st of the current year shall be notified by the Secretary. If the dues are still unpaid on July 1st further notice shall be given and a delinquent Member shall lose the right to vote. If the dues remain unpaid October 1st the person shall be notified on the form prescribed by the Board of Direction, and shall no longer receive the publications of the Association. If the dues are not paid by December 31st, the person shall forfeit membership without further action or notice, except as provided for in Section 4 of this Article.

4. Remission of Dues

The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member, Associate or Junior Member who, for good reason, is unable to pay them.

Article V

Officers

1. Officers

(a) The officers of the Association shall be a President, two Vice-Presidents, twelve Directors, a Secretary and a Treasurer.

(b) The President, the Vice-Presidents and the Directors, together with the two latest living Past-Presidents continuing to be members, shall constitute the Board of Direction, in which the government of the Association shall be vested; they shall act as the trustees and have the custody of all property belonging to the Association. The President, the Vice-Presidents and the Directors shall be members.

(c) The Secretary and the Treasurer shall be appointed by the Board of Direction.

(d) Provided, however, that in the first Association year following the amendment of the Constitution by the inclusion of this paragraph, the Board of Direction shall include ten Directors and the four latest living Past-Presidents continuing to be members, and that in the second Association year it shall include eleven Directors and the three latest living Past-Presidents continuing to be members.

2. Term of Office

The term of office of the President shall be one year, of the Vice-Presidents two years and of the Directors three years. The term of each shall begin at the close of the Annual Convention at which elected and continue until a successor is qualified. All other officers and employees shall hold office or position during the pleasure of the Board of Direction.

3. Officers Elected Annually

(a) There shall be elected at each annual convention a President, one Vice-President and four Directors.

(b) The candidates for President and for Vice-President shall be selected from the members or past members of the Board of Direction.

4. Conditions of Re-election of Officers

A President shall be ineligible for re-election. Vice-Presidents and Directors shall not be eligible for re-election to the same office until at least one full term has elapsed after the end of their respective terms.

5. Vacancies in Offices

(a) When a vacancy occurs in the office of President the duties shall be performed by the senior Vice-President.

(b) When a vacancy occurs in the office of either Vice-President the Board of Direction shall select a Vice-President from the members or past members of the Board of Direction. A Vice-Presidency shall not be considered vacant when one of the Vice-Presidents is filling a vacancy in the Presidency.

(c) A vacancy in the office of Director shall be filled by the Board of Direction.

(d) An incumbent in any office for an unexpired term shall be eligible for re-election to the office held; provided however, that anyone appointed to fill a vacancy as Director within six months after the term commences shall be considered as coming within the provisions of Article V, Section 4.

6. Vacation of Office

(a) When an elected officer ceases to be a Member of the Association, as provided in Article II, the office shall be vacated.

(b) In case of the disability of or neglect in the performance of duty by an officer, the Board of Direction, by a two-thirds affirmative vote of the entire Board, shall have the power to declare the office vacant.

Article VI

Nomination and Election of Officers

1. Nominating Committee

(a) There shall be a Nominating Committee composed of the five latest living Past-Presidents of the Association, who are Members, and five Members who are not officers.

(b) The five Members who are not Past-Presidents shall be elected annually for a term of one year, when the officers of the Association are elected.

(c) The senior Past-President who is a member of the Committee shall be the Chairman of the Committee. In the absence of the senior Past-President from a meeting of the Committee the Past-President next in seniority present shall act as Chairman.

2. Method of Nominating

(a) Prior to December 1st of each year the Chairman shall call a meeting of the Committee at a convenient place, at which nominees for the several elective offices shall be selected as follows:

Office to be Filled	*Number of Candidates to be named by the Nominating Committee.*	*Number of Candidates to be elected at the Annual Election of Officers.*
President	1	1
Vice-President	1	1
Directors	8	4
Nominating Committee	10	5

(b) The Chairman of the Nominating Committee shall send the names of the nominees to the President and Secretary not later than December 15th of the same year, and the Secretary shall report them to the members of the Association on a printed slip not later than January 1st following.

(c) At any time between January 1st and February 1st any ten or more Members may send to the Secretary additional nominations for any elective office for the ensuing year signed by such Members.

(d) If any person nominated shall be found by the Board of Direction to be ineligible for the office for which nominated, or should a nominee decline such nomination, the name shall be withdrawn. The Board of Direction may fill any vacancies that may occur in the list of nominees up to the time the ballots are sent out.

3. Ballots Issued

Not less than thirty days prior to each Annual Convention, the Secretary shall issue a ballot to each voting member of record in good standing, listing the several candidates to be voted upon. When there is more than one candidate for any office, the names shall be arranged on the ballot in the order that shall be determined by lot by the Nominating Committee. The ballot shall be accompanied by a statement giving for each candidate, his record of membership and activities in this Association.

4. Substitution of Names

Members may erase names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

5. Ballots

(a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed to or deposited with the Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw a ballot, and cast another, at any time before the polls close.

(c) Ballots not endorsed or from persons not qualified to vote shall not be counted.

(d) The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

6. Closure of Polls

The polls shall be closed at twelve o'clock noon on the second day of the Annual Convention, and the ballots shall be counted by tellers appointed by the Presiding Officer.

7. Election

(a) The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

(b) In case of a tie between two or more candidates for the same office, the Members present at the Annual Convention shall elect the officer by ballot from the candidates so tied.

(c) The Presiding Officer shall announce at the convention the names of the officers elected in accordance with this Article.

Article VII

Management

1. President

The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and shall be ex-officio a member of all committees, except the Nominating Committee.

2. Vice-Presidents

The Vice-Presidents, in order of seniority, shall preside at meetings in the absence of the President and shall discharge the duties in case of a vacancy in the office.

3. Treasurer

The Treasurer shall receive all monies, deposit the same in the name of the Association, receipt to the Secretary therefor and invest all funds not needed for current disbursements as shall be ordered by the Board of Direction. The Treasurer shall pay all bills, when properly certified and audited by the Finance Committee, and make such reports as may be called for by the Board of Direction.

4. Secretary

The Secretary, shall be under the direction of the President and Board of Direction, the Executive Officer of the Association and shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and duly record the proceedings thereof. The Secretary shall see that the monies due the Association are collected and without loss transferred to the custody of the Treasurer, and shall personally certify to the accuracy of all bills or vouchers on which money is to be paid. The Secretary is to conduct the correspondence of the Association, keep proper record thereof, and perform such other duties as the Board of Direction may prescribe.

5. Auditing of Accounts

The accounts of the Treasurer and of the Secretary shall be audited annually by an approved accountant under the direction of the Finance Committee of the Board of Direction.

6. Board of Direction

(a) The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided in the Constitution.

(b) The Board of Direction shall meet within thirty days after each Annual Convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board of Direction.

(c) Seven members of the Board of Direction shall constitute a quorum.

(d) At the first meeting of the Board of Direction after the Annual Convention, the following committees, each consisting of not less than three members, shall be appointed by the President from the Board of Direction and they shall report to and perform their duties under the supervision of the Board of Direction.

Finance
Publication
Outline of Work of Committees
Personnel of Committees
Membership
Manual

7. Duties of the Committees of the Board of Direction

(a) Finance Committee

The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of monies and other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by authority of the Board of Direction.

(b) Publication Committee

The Publication Committee shall have general supervision of the publications of the Association. The Publication Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money except by authority of the Board of Direction.

(c) Committee on Outline of Work of Committees

The Committee on Outline of Work of Committees shall prepare and present to the Board of Direction a report of the subjects to be investigated, considered and reported upon by the standing and special committees of the Association during the ensuing year.

(d) Committee on Personnel of Committees

The Committee on Personnel of Committees shall prepare and present to the Board of Direction a list of chairmen, vice-chairmen and members of the standing and special committees of the Association for the ensuing year.

(e) Membership Committee

The Membership Committee shall make investigation of applicants for membership and shall make recommendations to the Board of Direction with reference thereto.

(f) Manual Committee

The Manual Committee shall study and recommend to the Board of Direction as to the manner in which the material adopted for addition or deletion from the Manual shall be handled.

8. Standing Committees

The Board of Direction may appoint standing committees to investigate, consider and report upon questions pertaining to railway location, construction, operation and maintenance.

9. Special Committees

The Board of Direction may appoint special committees to examine into and report upon any subject connected with the objects of this Association.

10. Discussion by Non-Members

The Board of Direction may invite discussions of reports from persons not members of the Association.

11. Sanction of Act of Board of Direction

An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next annual convention of the Association shall be deemed to be the act of the Association.

Article VIII

Meetings

1. Annual Convention

(a) The Annual Convention of the Association shall be held in the City of Chicago, Illinois. The convention shall open on a Tuesday in the month of March to be determined by the President.

(b) The Secretary shall notify all members of the Association of the time and place of the Annual Convention at least thirty (30) days in advance thereof.

(c) The order of business at the Annual Convention of the Association shall be:

Reading of the Minutes of the last meeting
Address of the President
Reports of the Secretary and the Treasurer
Reports of Committees
Unfinished Business
New Business
Installation of Officers
Adjournment

(d) This order of business may be changed by a majority vote of Members present.

(e) The proceedings shall be governed by "Robert's Rules of Order" except as otherwise herein provided.

(f) Discussions shall be limited to members and to those others invited by the Presiding Officer to speak.

2. Special Meetings

Special meetings of the Association may be called by the Board of Direction and special meetings shall be so called by the Board of Direction upon written request of thirty Members. The request shall state the purpose of such meeting.

The call for such special meeting shall be issued not less than ten (10) days in advance and shall state the purpose and place of the meeting. No other business shall be taken up at such meeting.

3. Quorum

Twenty-five (25) Members shall constitute a quorum at all meetings of the Association.

Article IX

Amendment

1. Amendment

Proposed Amendment of this Constitution shall be made in writing, shall be signed by not less than ten Members and shall be acted upon in the following manner:

The amendment shall be presented to the Secretary, who shall send a copy to each member of the Board of Direction as soon as received. If a majority of the entire Board of Direction so votes the matter shall be submitted to the Association by letter-ballot.

The Board of Direction shall canvass the ballots which have been received within sixty days after the date of issue of the letter-ballot and if two-thirds (⅔) of the votes so received are in the affirmative the amendment shall be declared adopted and shall become immediately effective.

The result shall be announced at the next Annual Convention.

GENERAL INFORMATION

(Revised to March 1947)

GENERAL RULES FOR THE PREPARATION, PUBLICATION AND CONSIDERATION OF COMMITTEE REPORTS

(A) Appointment of Committees and Outline of Work

Standing Committees

1. The following are Standing Committees:

1. Roadway and Ballast.
3. Ties.
4. Rail.
5. Track.
6. Buildings.
7. Wood Bridges and Trestles.
8. Masonry.
9. Highways.
11. Records and Accounts.
13. Water Service and Sanitation.
14. Yards and Terminals.
15. Iron and Steel Structures.
16. Economics of Railway Location and Operation.
17. Wood Preservation.
20. Uniform General Contract Forms.
22. Economics of Railway Labor.
24. Cooperative Relations with Universities.
27. Maintenance of Way Work Equipment.
28. Clearances.
29. Waterproofing.
30. Impact and Bridge Stresses.

Special Committees

2. Special Committees will be appointed from time to time, as may be deemed expedient, in the manner prescribed by Article VII, Section 9, of the Constitution.

Personnel of Committees

3. The personnel of all committees shall be revised annually. It is desirable that 10 percent of the membership be changed each year. Members who do not attend meetings of the committees during the year or render no service by correspondence will be replaced. The terms of chairmen and vice-chairmen shall be three years in each position.

Outline of Work

4. As soon as practicable after the reports of committees for the current year have been filed with the secretary, the Board of Direction will assign to the committees, subjects which in its judgment should preferably be considered during the succeeding year, provided, however, that such assignments may be subject to revision until the close of the annual convention. *Such assignments should not be deviated from except in extreme cases and then not until approved by the Committee on Outline of Work.*

(B) Preparation of Committee Reports

General

5. The objectives of the Association are advanced through the work of the committees in two ways—(1) the development of useful information pertinent to their assignments to be presented to the Association "as information," and (2) the formulation of recommended practices to be submitted for adoption and publication in the Manual.

(a) Whether the report on any particular assignment should take the form of "information" or a "recommended practice," depends largely on the nature of the assignment. Some assignments will be fulfilled completely by the presentation of information; others call for information in support of appended recommendations that are submitted for adoption. In still other cases, the primary objective is a comprehensive statement of recommended practices, but the development of these recommended practices may entail investigation or research work, the results of which are of such importance as to warrant their presentation as information prior to the submission of the recommendations. In some cases, also, it may be advisable to submit as information matter in the form of recommended practice, with a view to inviting suggestions and criticisms that may serve as the basis for revisions prior to the resubmission of the matter for adoption a year later.

Planning the Work

6. In pursuing the work on any assignment, the first step is necessarily one of fact finding, including (a) a study of available literature on the subject, particularly reports of previous investigations, (b) a compilation of current practice, especially recent changes in practice, and (c) resort to original tests or experimentation, after a canvass of all other sources of information indicates that research work is necessary.

Collection of Data

(a) Committees are privileged to obtain data or information in any proper way. If desired, the secretary will issue circulars of inquiry, which should be brief and concise. The questions asked should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. They should specify to whom answers are to be sent, and should be in such form that copies can be retained by persons replying either by typewriter or blueprint.

(b) Requests for appropriations for the conduct of research work should be sent to the secretary with a supporting statement setting forth: (a) the nature of the information sought; (b) how the railroads are adversely affected by the lack of this information; (c) the estimated cost of the investigation; (d) the estimated time to complete the work; (e) the basis for assuming that the investigation will produce the data desired; and, (f) an estimate of the savings to be realized or other advantages to accrue from the successful completion of the investigations. A request for funds to continue or complete an investigation shall include a statement of the results obtained to date.

Reports

7. Committees should pursue their investigations on all assignments but are expected to present progress or final reports for publication only on those assignments regarding which pertinent information has been developed.

(a) Committees are privileged to present the results of any special study or investigation they may be engaged upon in connection with their assignments that may be considered of sufficient importance to warrant presentation.

(b) Reports of information, supplementing previous reports of progress, may include a brief review of matter previously presented, but should avoid extended repetition of such matter.

(c) Matter offered for adoption and publication in the Manual should be submitted in full, regardless of its publication in previous years unless the matter being offered appeared in substantially identical form not more than one year before being submitted for adoption.

(d) Illustrations accompanying reports should, when possible, be prepared so that they can be reproduced on one page. The use of inserts should be avoided.

(e) One of the most important duties of each committee is to examine its own subject matter in the Manual each year and submit such revisions of or supplements to the Manual as are deemed necessary to keep it up to date. New matter for publication in the Manual and revisions thereof must be submitted in the form and manner specified in the General Rules for Publication of the Manual.

(f) Committees are required to resubmit all items in their respective chapters of the Manual at intervals of not less than 10 years, either with desired revisions or with a request for reapproval without change.

Form of Reports

8. Committee reports shall be prepared in accordance with the Style Standards for Committee Reports.

(C) Publication of Reports

Dates for Filing and Publication of Reports

9. For the convenience of those attending the convention, the reports of committees to be presented at any session of the annual convention will be published, so far as possible, in the same bulletin. To carry out this plan requires a careful scheduling of the filing of reports and the publication of bulletins, and the arrangement of the convention program. It is of utmost importance that chairmen file complete reports of their committees on or before the dates specified on the schedule furnished them.

Written Discussions

10. Written discussions of published reports will be transmitted to the chairman of the interested committee who will read or present them by title or in abstract at the convention. Written discussions will be published in the Proceedings as a part of the discussion of the committee reports.

Verbal Discussions

11. When necessary to insure accuracy, the speaker's remarks will be submitted to him in writing before publication in the Proceedings, for the correction of diction and errors of reporting, but not for the elimination of remarks.

(D) Consideration of Committee Reports

Sequence

12. The sequence in which committee reports will be considered by the convention will be determined by the Board of Direction.

Method

13. Reports offered as information will be presented by title or by a brief outline of the contents. Comments or criticisms may be offered from the floor upon invitation from the presiding officer.

14. Matter submitted for adoption and publication in the Manual may receive consideration by one of the following procedures:

(a) Reading by title.
(b) Reading, discussing and acting upon each conclusion separately.
(c) By majority vote, discussion will be had on each item. Clauses not objected to when read will be considered as voted upon and adopted.

Action on Reports

15. No formal action is to be taken by the convention on matter submitted as information, whether in the form of a progress or final report.

Action on matter submitted for adoption and publication in the Manual will be one of the following:

(a) Adoption as a whole as presented.
(b) Affirmative action on the amendment of a part or parts of the matter presented, followed by adoption as a whole, as amended.
(c) Adoption of a part, complete in itself, and referring of remainder back to the committee.
(d) Recommittal with or without instructions.

NOTE.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the committee considers affected.

The Chair will decline to entertain amendments which in his opinion are primarily a matter of editing.

(E) Publication of Abstracts by Technical Journals

The following rules will govern the releasing of matter for publication in technical journals:

Committee reports, requiring action by the Association at the annual convention, will not be released until after presentation to the convention; special articles, contributed by members and others, on which no action by the Association is necessary, are to be released for publication by the technical journals after issuance in the bulletin; provided, application therefor is made in writing and proper credit be given the Association. authors or committees presenting such material.

GENERAL RULES FOR PUBLICATION OF THE MANUAL

Title

1. The title of the volume will be "Manual of the American Railway Engineering Association."

2. The Board of Direction shall have the authority to withhold from publication any matter which it shall consider as not desirable to publish, or as not being in proper shape, or as not having received proper study and consideration.

Contents

3. The matter adopted by the Association for publication in the Manual shall be considered Recommended Practice, but shall not be binding on the members. Recommended Practice, as defined by the Board of Direction (May 20, 1936) is a material device, plan, specification or practice recommended to the railways for use as required. either exactly as presented or with such modifications as may be necessary or desirable to meet the needs of individual railways, but in either event, with a view to promoting efficiency or economy, or both, in the location, construction, operation or maintenance of railways.

Requisites for Adoption

4. The Manual will include only such matter as has been made the subject of a special study by a standing or special committee and embodied in a committee report after it has received a two-thirds majority in a letter ballot of all Members of the committee (Associate members are not entitled to vote), and shall include only such matter as has been published not less than 30 days prior to the annual convention, and submitted by the committee to the annual convention, and which, after due consideration and discussion, shall have been voted on and formally adopted by the Association. Subjects which, in the opinion of the Board of Direction shall be reviewed by the Association of American Railroads, may be referred to that association before being published in the Manual.

5. When and as required, recommendations for the adoption or revision of Manual material shall be submitted to letter ballot of the Members of the Association under the following limitations:

(a) That the letter ballot shall be taken only after the Board of Direction has recognized the necessity for such emergency action, and

(b) That the propositions submitted by the committee shall have the approval of a special committee of the Board of Direction appointed by the President for that purpose, both as to the substance of the material offered and also as to the circumstances attending the consideration of the material by the committee.

6. All conclusions included in the Manual must be in concise and proper shape for publication, as the Manual will consist only of a summary record of the definitions, specifications and principles of practice adopted by the Association, with a brief reference to the published Proceedings of the Association for the context of the committee report and subsequent discussion and the final action of the Association.

Revision

7. Any matter in the Manual may be amended or withdrawn either by vote at any subsequent annual convention or by letter ballot, provided such changes are proposed in time for publication not less than 30 days prior to the annual convention, and in the following manner: (a) upon recommendation of the committee in charge of the subject; (b) upon recommendation of the Board of Direction; (c) upon request of five members made to the Board of Direction.

8. Revisions of or additions to the Manual authorized by action at each convention will be published annually in the form of loose-leaf sheets which will be made available to all holders of the Manual. These supplemental sheets will be accompanied by instructions for insertion of the new sheets and the withdrawal of sheets that have been superseded, as well as those that have been withdrawn by action of the Association.

REPORT OF THE SECRETARY

March 1, 1948.

To the Members:

The most important event in the affairs of the American Railway Engineering Association during 1947 was the referendum of the membership on an increase in the annual dues from $10 to $15, effective January 1, 1948. The result of the letter ballot, as reported by the tellers on November 6, was 814 in favor and 154 opposed.

Due to the extraordinary number of applications for membership received during the year, deferred disbursements and a windfall in the form of a tax refund, the large deficit which had been the basis for the proposition to increase the dues did not materialize, the receipts exceeding the expenditures by $4.04. These circumstances, which proved advantageous from the standpoint of 1947, are either non-repetitive in 1948 or will result in definite disadvantages, but it is anticipated that the increase in the dues will enable the Association to operate on a balanced budget during the year.

The net membership increase during the year was 118, bringing the total number of members to 2334, the highest level since 1932. There has been an increase in the number of members who are identified with the committee work, and while the number of pages of committee reports is somewhat less than was published a year earlier, there has been a general stepping up of committee activity. The sale of publications continues on a high level, although there has been some falling off from the demand created by the war.

Finances

The financial statement for the calendar year of 1947, which appears in full on following pages, may be summarized as follows:

Receipts	$46,993.07
Disbursements	46,989.03
Excess of receipts over disbursements	$4.04

This statement fails to present an accurate picture, as can be readily explained. The disbursements were lower than had been anticipated by about $3000, because of the failure of delivery before the end of the year of 500 new Manual binders and a complete reprinting of the Portfolio of Trackwork Plans. On the other hand, the revenues include an item of over $1200 that is essentially a windfall, because it represents a refund of federal unemployment tax payments of the preceding four years. Therefore, except for these circumstances the finances of the Association would have shown a deficit in excess of $4300 in spite of a continued high level of publication sales and a greater number of applications for membership than in any other year in the last 20.

In the meantime an analysis of the operating expenses discloses a continuing upward trend in unit costs of items that loom large in the Association's basic needs. Speculations as to the outcome of the operations for 1948 indicate a balanced budget, provided there is not too great a falling off of the volume of membership applications and purchases of publications, and that the volume of printing is not unduly high. As the printing is a function of the productivity of the committees and cannot be subject to any rigid control, an accurate forecast is not possible.

COMPARISON OF RECEIPTS AND DISBURSEMENTS FOR A 12-YEAR PERIOD

	Receipts	*Disbursements*	*Net Gain*
1935	$29,001	$30,110	$1,109*
1936	28,643	34,662	6,019*
1937	36,523	32,200	4,323
1938	28,422	23,394	5,028
1939	28,189	23,847	4,342
1940	28,272	26,451	1,821
1941	32,433	29,384	3,049
1942	31,500	26,692	4,808
1943	28,736	23,809	4,927
1944	30,492	26,534	3,958
1945	32,305	29,305	3,000
1946	28,836	34,583	5,747*
1947	46,933	46,989	4

* Deficits.

Membership

The membership record for the period February 1, 1947, to February 1, 1948, was as follows:

Members on the rolls as of February 1, 1947		2216
New members		223
Reinstatements		21
		2460
Deceased	37	
Resigned	51	
Dropped	38	126
		2334
Net gain	118	
Membership as of February 1, 1948		2334

The total membership as of February 1, 1948 was the largest since February 1932, while the net increase in the membership during the last 12 months was greater than in any corresponding period since 1929. Of even greater interest is the fact that the total of 2334 as of February 1 of this year indicates an increase of 454 members, or about 24 percent, over the number on March 1, 1939, when the membership reached the lowest level as the result of the depression.

It will be observed in the table of members by classes that the number of life members is still increasing, thus indicating the influence of retirements deferred during the war and of the trend toward earlier retirement ages adopted by some of the railroads. A pronounced growth in the Junior membership grade is still to be realized.

During the year ending with February 1, 1948, the Association lost 37 members by death, as listed in the roll of deceased members appearing at the end of this report. Among these were two past presidents, G. W. Kittredge and W. D. Faucette, three charter members, F. H. Alfred, J. R. W. Davis and E. E. R. Tratman, two former committee chairmen, A. P. Button and C. C. Westfall, and a vice-chairman, L. H. Roden. Also included was Professor N. J. Alleman, who had been prominently identified with the research work on rail and rail joints,

The classification of the membership February 1, 1948, as compared with corresponding dates in the four previous years was as follows:

	1944	*1945*	*1946*	*1947*	*1948*
Life	182	197	246	277	294
Member	1,485	1,515	1,564	1,618	1,686
Associate	257	259	262	287	317
Junior	38	33	35	34	37
	1,962	2,004	2,107	2,216	2,334

Publications

Because of the concentration of lengthy reports on research work for the committees on Roadway and Ballast, on Track and on Rail a year ago, there was a total of 340 pages of report material in the bulletin for February 1947. To offer such a mass of printed matter to the members only 30 days in advance of the annual meeting was obviously a disservice to them. The size of that bulletin also led to some serious questions regarding the overall policy of the form and content of reports on scientific investigations. Also involved was the threat of mounting costs of printing. As a consequence a concerted effort was made for both condensation of report material and a rescheduling of publication dates. Instead of attempting to crowd as many as possible of the reports on research into the January and February bulletins, more of the material is to appear in the two summer bulletins. The effect of this new policy is apparent in the smaller size of the February 1948 bulletin, which contains 212 pages, or 126 less pages than last year. It is also indicated by the fact that the seven bulletins ending with February 1948 contained a total of 848 pages, compared with 1014 pages in the corresponding bulletins a year earlier. While these figures would indicate that material progress has been made toward the desired objective, there is still a considerable lack of balance in the size of the individual reports. Some of them do not occupy as many pages because several of the subcommittees presented no reports at all, rather than because of an effort at condensation of the texts of the reports included.

Contents of Bulletin 469, June–July 1947

Effect of Weight Redistribution on the Magnitude of Lateral Forces Exerted by a Locomotive

Investigation of Bridge Impacts with a Mechanical Oscillator

Preliminary Report of Committee 3—Ties

Rational Design of Sections for Short Compression Members of Steel—L. T. Wyly

Memoir—William Dollison Faucette

Memoir—Louis Yager

Contents of Bulletin 468, September–October 1947

Impact Test on Two Truss Spans—Toledo Terminal Railroad

Vol. 48 of the Proceedings (1947) contained 1032 pages, compared with 786 pages in Vol. 47 (1946). It was larger by 100 pages than any other volume of the Proceedings since 1941.

The Manual

The servicing of the Manual is still one of the most exacting tasks imposed on the Association's staff. Depletion of the stock due to war-created demands required the reprinting of the Manual during the second half of 1946, but the work was not completed until January 1947. However, because of the enforced curtailment of committee work during the war, many needed revisions of the Manual were not completed in advance of the reprinting, as was done prior to the initial publication of the Manual in loose-leaf form in 1935–1936. Actually, the supplements in 1945 and 1946 were much smaller than usual. As a result the 1946 reprinting was followed by the publication of one of the largest supplements ever issued, with the prospect that the supplements for several years to come may be as large or larger.

The magnitude of the task of collating several hundred supplements with as many copies of the Manual will be readily appreciated by anyone who corrects his own Manual upon receipt of the annual supplement. It is necessary to bear in mind that the corresponding corrections must be made also in the Association's stock of individual chapters that have to be made available for sale separately. In this connection it is appropriate to direct attention to an important by-product of the publication of the Manual in loose-leaf form, namely, the impetus that has been given to the demand for individual parts thereof. Initially, the Board of Direction was reluctant to encourage purchase of the Manual in other than complete form, but finally consented to the breaking up of a few volumes for sale as separate chapters, particularly, the chapters on Rail, Track, Masonry, Iron and Steel Structures, Clearances and Waterproofing. This demand was

Record of Manual Supplements

Supplement	*New Sheets Issued*	*Old Sheets Withdrawn*	*Net Increase*
1937	110	69	41
1938	151	121	30
1939	128	95	33
1940	185	139	46
1941	148	120	28
1942	144	149	—5
1943	176	158	18
1944	131	109	22
1945	44	45	—1
1946	127	147	—20
1947	167	184	—17
Total	1,511	1,336	175

increased markedly during the war and was supplemented by a call for an increasing number of parts of chapters, particularly, certain of the specifications for track materials, culverts, concrete masonry, ties and structural timbers. More widely used than any other part of the Manual are the Specifications for Steel Railway Bridges, not only as employed in design and construction but also as a standard text in engineering schools.

Work Equipment Handbook

During the last year the Association launched a new publication known as the Manual of Instruction for the Care and Operation of Maintenance of Way Work Equipment. Following a canvass of the potential demand, 8000 copies were printed, but because actual orders proved larger than the inquiries, the supply is exhausted, pending a second printing.

Work of the Committees

The Committee on Waterways and Harbors was disbanded with the close of the annual meeting of the Association in March 1947, thereby reducing the number of committees to 21. However, the total of the personnel of these 21 committees as of April 1, 1947 was 853, compared with 849 for the 22 committees of the previous year. Since that time there has been an appreciable stepping up of committee personnel so that, including members appointed for service beginning with the ensuing Association year, about 733 members will occupy 875 places on the 21 committees. It is doubtful if there is any other organization in which such a large proportion of the total membership participates in the committee work.

Because of the marked increase in retirements from railway service and the addition of a large number of new members to the rolls, the turnover among committee members has been far above normal, thereby greatly increasing the amount of paper work imposed on the chairmen as well as the Association's office staff. The chairmen were also faced with an innovation in committee procedure by reason of the new rule which requires two-thirds affirmative vote by letter ballot of the committee before any recommendation affecting the Manual can be placed before the Association in the form of a report. This has of course involved the chairmen in further office routines, although the adoption of uniform practice in this regard may result in some simplification of the requirements.

There has been an increase in committee activity, both in the number of meetings and in the attendance at meetings. Six committees held one meeting only, six others held two meetings each, eight held three meetings each and one held four meetings, a total of 46 meetings, or two more than in the previous year. There was also a wider distribution of the places of meeting, although Chicago still held first place by a wide margin, with 28 meetings. There were three meetings at Washington, D. C., two each at Buffalo, N. Y., and Houston, Tex., and one meeting each at 11 other cities.

While the total volume of committee reports as measured in pages was less than in the previous year, the total number of subjects covered was larger, as is brought out in the tabular classification of the material. Attention is directed to the appearance in this table for the first time of the third item designated as "Reapproval of Manual Material," which accounts for part of the increase in the total recorded.

Classification of Material in the Reports

	1943	*1944*	*1945*	*1946*	*1947*	*1948*
Revisions of the Manual—minor	4	6	6	10	13	36
Revisions of the Manual—major	4	6	..	7	11	22
Reapproval of Manual material	..	..	..	..	..	23
New Manual material—minor	2	..	1	..	2	1
New Manual material—major	9	10	2	3	3	4
New Manual material—tentative	5	2	2	1	5	7
Information	41	45	33	32	33	29
Reports on research work	11	12	12	14	15	16
Reports on service tests	4	2	4	5	6	3
Statistical data	7	5	3	2	2	3
Analytical studies	5	2	2	2	2	8
Bibliographies	2	3	2	2	2	2
Brief report of progress	5	18	7	7	13	16
War emergency provisions and reports	13	4	4	1	..	..
	112	115	76	86	107	170

Research Work

The essential facts concerning the research work in progress during the last year and the program authorized for the current year are brought out clearly in the large table, which lists each item authorized for 1946, 1947 and 1948. As will be seen, the appropriation of the Association of American Railroads for the investigations to be carried out by the Engineering Division during 1948, most of which relates to matters

ENGINEERING DIVISION ALLOTMENTS FOR RESEARCH

	1946 Budget	*1947 Budget*	*1948 Budget*
Committee on Rail			
Transverse fissure investigation	$ 6,000	$ 5,000	$ 5,000
Investigation of shelly spots	13,000	13,000	13,000
Rail investigations committee	6,938	7,713	8,996
Service tests of joint bars	2,980	3,200	8,500
Rolling-load tests of joint bars	7,000	7,000	8,500
Investigation of driver burns	11,000	6,000	6,000
Rail design investigation	15,000	15,000	15,800
Total	$ 61,918	$ 56,913	$ 65,796
Committee on Track			
Stresses in tie plates	$ 10,000	$ 10,000	$ 10,620
Bolt tension and joint lubrication	4,500	4,500	4,800
Corrosion from brine drippings	1,000	1,000	1,000
Stresses in manganese frogs	5,000	5,000	5,380
Tests of rail anchorage	3,000	3,000	3,180
Tie plate fastenings	....	10,000	10,800
Welding of manganese frogs	1,000	....	....
Total	$ 24,500	$ 33,500	$ 35,780
Relation Between Track and Equipment			
Rail and wheel gage and contour	$ 10,000	$ 10,000	$ 10,400
Relation, wheel load-wheel diameter	5,000	5,000	5,500
Flat spot investigation	10,000	10,000	....
Lateral forces from locomotives	....	25,000	10,700
Total	$ 25,000	$ 50,000	$ 26,600
Structural Projects			
Impact investigation	$ 16,000	$ 45,000	$ 79,500
Waterproofing investigation	....	10,000	10,000
Floorbeam hangers	....	5,000	10,000
Fatigue strength of riveted and bolted joints	5,000	5,000	5,000
Fatigue tests of butt-welded beams	....	....	2,000
Total	$ 21,000	$ 65,000	$106,500
Miscellaneous			
Research office	$ 11,092	$ 13,015	$ 16,164
Electrolysis study	1,000	1,000	1,000
Roadbed stabilization	15,000	15,000	20,000
Wear and splitting of ties	....	....	20,000
Total	$ 27,092	$ 29,015	$ 57,164
GRAND TOTAL	$159,510	$234,428	$291,840

of interest to AREA committees, is $291,840 and as will be observed in the table of allotments for the last 11 years, this sum is more than twice the appropriation for 1946 and four times as much as was authorized in 1940. While there have been increases in the allotments to several of the projects, the largest expansion of activity has been provided in the work on impact and bridge stresses from $45,000 in 1947 to $79,500 for 1948. Also included is a fund of $20,000 comprising an initial contribution to a comprehensive study of the cause and prevention of the wear and splitting of cross ties.

Total Allotments for Research, Engineering Division, 1938–1948:

1938	$78,158	1944	$109,050
1939	78,650	1945	138,110
1940	69,250	1946	159,510
1941	95,150	1947	234,428
1942	87,930	1948	291,840
1943	98,445		

W. S. Lacher,
Secretary.

Deceased Members

G. J. ADAMSON
Engineering Assistant to Vice-President, Union Pacific Railroad, Omaha, Nebr.

F. H. ALFRED
Retired President, Pere Marquette Railway, Orlando, Fla.

N. J. ALLEMAN
Special Research Associate Professor in Engineering Materials, University of Illinois, Urbana, Ill.

F. W. BROWN
Vice-President, Atlantic Coast Line Railroad, Wilmington, N. C.

H. L. BUNN
Assistant Engineer, Texas & Pacific Railway, Alexandria, La.

A. C. BUTTERWORTH
President, General Material Company, St. Louis, Mo.

A. P. BUTTON
Assistant to Chief Engineer, New York Central System, Chicago, Ill.

H. K. CARTER
Assistant Division Engineer, New York Central System, Bellefontaine, Ohio

C. K. CONARD
New Paltz, N. Y.

J. R. W. DAVIS
Retired Chief Engineer, Great Northern Railway, Seattle, Wash.

JOHN EVANS
Special Engineer, Michigan Central Railroad, Detroit, Mich.

W. D. FAUCETTE
Executive Representative, Seaboard Air Line Railroad, Norfolk, Va.

D. X. GREENBERG
Assistant Engineer, Missouri Pacific Railroad, Kirkwood, Mo.

L. D. HAMERSKI
Assistant Engineer, Minneapolis, St. Paul & Sault Ste. Marie Railway, Minneapolis, Minn.

B. B. HARRIS
Vice-President, Philippine Railway, Brooklyn, N. Y.

F. W. HAWKS
Retired Valuation Engineer, Virginian Railway, Norfolk, Va.

F. A. HIPPEY
(In Armed Service)

R. S. HUBLEY
Inspecting Engineer of Wood Preservation, Great Northern Railway, St. Paul, Minn.

F. P. HUSTON
In Charge of Railroad Development, International Nickel Company, New York, N. Y.

T. T. Irving
Retired Chief Engineer, Central Region, Canadian National Railways, Orlando, Fla.

C. W. Johnson
President, G. A. Johnson & Son, Chicago, Ill.

C. S. Joseph
Principal Assistant Engineer, Georgia Railroad, Atlanta, Ga.

Otto Joslin
Senior Assistant Engineer, Nashville, Chattanooga & St. Louis Railway, Nashville, Tenn.

R. A. Kane
Structural Engineer, Union Pacific System, Omaha, Nebr.

G. W. Kittredge
Retired Chief Engineer, New York Central System, Yonkers, N. Y.

G. A. Maney
Chairman, Civil Engineering Department, Northwestern Technological Institute, Evanston, Ill.

A. C. Mann
Vice-President Purchases and Stores, Illinois Central Railroad, Chicago, Ill.

J. B. Martin
General Inspector, Woodings–Verona Tool Works, Chicago, Ill.

L. B. Martin
Superintendent, Electric Division, Illinois Terminal Railroad, Springfield, Ill.

W. S. Newhall
Chagrin Falls, Ohio

H. H. Richardson
Assistant Vice-President, National Aluminate Corporation, Chicago, Ill.

L. H. Roden
Assistant Engineer, Chesapeake & Ohio Railway, Richmond, Va.

E. I. Rogers
Retired President, Peoria & Pekin Union Railway, Peoria, Ill.

Paul Sterling
Assistant to Chief Engineer, New York, New Haven & Hartford Railroad, New Haven, Conn.

J. D. Sutphen
Office Engineer Southern Railway System, Charlotte, N. C.

E. E. R. Tratman
Civil Engineer, Wheaton, Ill.

Otis Weeks
Retired Division Engineer, Southern Pacific Company, Ogden, Utah

C. C. Westfall
Engineer of Bridges, Illinois Central Railroad, Chicago, Ill.

C. C. Williams
Madison, Wis.

FINANCIAL STATEMENT FOR CALENDAR YEAR ENDING DECEMBER 31, 1947

Balance on hand January 1, 1947			$101,522.53
RECEIPTS			
Membership Account			
Entrance Fees	$ 2,100.00		
Dues	20,423.25		
Binding Proceedings	1,370.94		
		$23,894.19	
Sales of Publications			
Proceedings	$ 1,671.58		
Bulletins	1,662.93		
Manuals	6,395.08		
Specifications	1,813.03		
Track Plans	2,585.87		
Handbooks	3,000.00		
		$17,128.49	
Advertising			
Publications		2,268.22	
Interest Account			
Interest on Investments	$ 2,417.17		
Less Interest Paid on Bonds Purchased	18.40		
		2,398.77	
Miscellaneous		1,303.40	
Total		$46,993.07	
DISBURSEMENTS			
Salaries		$14,510.65	
Proceedings		6,329.51	
Bulletins		6,520.73	
Stationery and Printing		1,758.61	
Rents, Lights, etc.		780.00	
Supplies		117.54	
Postage		1,056.49	
Refunds, Dues, etc.		76.60	
Audit, Year 1946		350.00	
Pension		1,200.00	
Social Security and Unemployment Taxes		895.49	
Manual		6,827.02	
Track Plans		1,322.71	
Committee and Officers Expense		72.93	
Annual Meeting Expense		1,202.97	
News Letter		1,418.75	
Handbooks		2,188.00	
Miscellaneous and Extraordinary		361.03	
Total		$46,989.03	
Excess of Receipts over Disbursements			4.04
Balance on hand December 31, 1947			$101,526.57

REPORT OF THE TREASURER

To the Members:

Balance on hand January 1, 1947		$101,522.53
Receipts during 1947	$46,993.07	
Paid out on Audited Vouchers	46,989.03	
Excess of Receipts over Disbursements		4.04
Balance on hand December 31, 1947		$101,526.57
Consisting of		
Bonds at cost		95,162.64
Cash in Northern Trust Company Bank		6,338.93
Petty Cash		25.00
		$101,526.57

We have made an audit of the accounts of the American Railway Engineering Association for the year ending December 31, 1947, and find them to be in accordance with the foregoing statements.

CARL BICK
PAUL MITCHELL
Auditors

GENERAL BALANCE SHEETS

December 31, 1947

ASSETS	*1947*	*1946*
Due from Members	$ 857.50	$ 551.50
Due from Sales of Publications	97.75	81.10
Due from Advertising	266.00	174.00
Furniture and Fixtures	570.18	452.42
Publications on hand (estimated)	630.00	700.00
Investments (cost)	95,162.64	90,588.51
Interest on Investments (accrued)	616.44	605.19
Cash in Northern Trust Company Bank	6,338.93	8,856.26
Cash in Royal Bank of Canada	....	2,052.76
Petty Cash	25.00	25.00
Manuals (on hand)	9,220.00	3,051.66
Track Plans	400.00	730.00
Paper Stock	305.10	546.96
Total	$114,489.54	$108,415.36
LIABILITIES		
Members' Dues Paid in Advance	$ 263.50	$ 252.50
Surplus	114,226.04	108.162.86
Total	$114,489.54	$108,415.36

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